Instrument Issue

Sci. Rm.

SCIENCE

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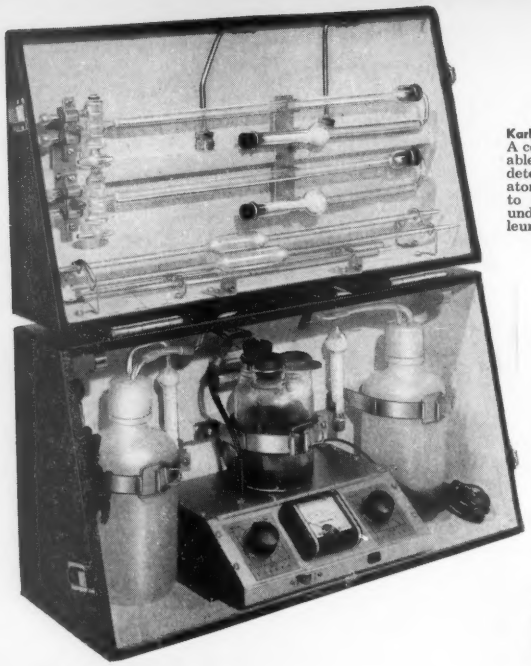
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

For EFI



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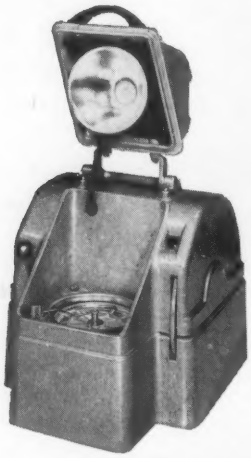

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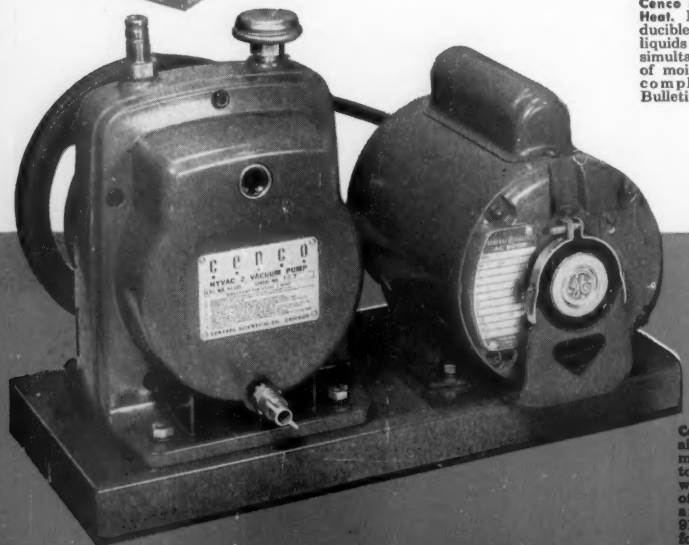

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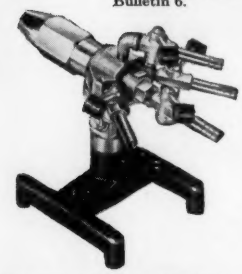

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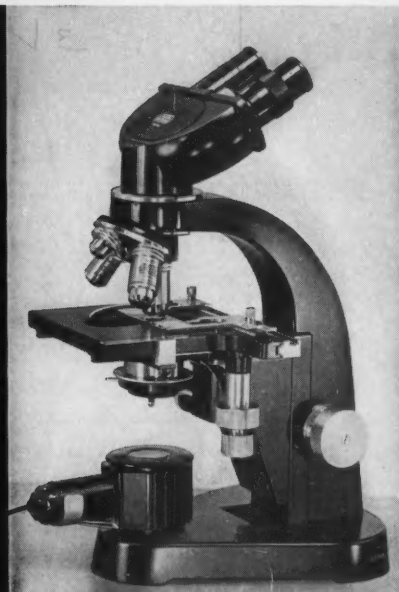
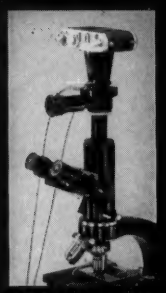
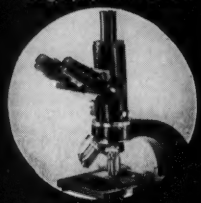




LABOLUX for photomicrography with LEICA.



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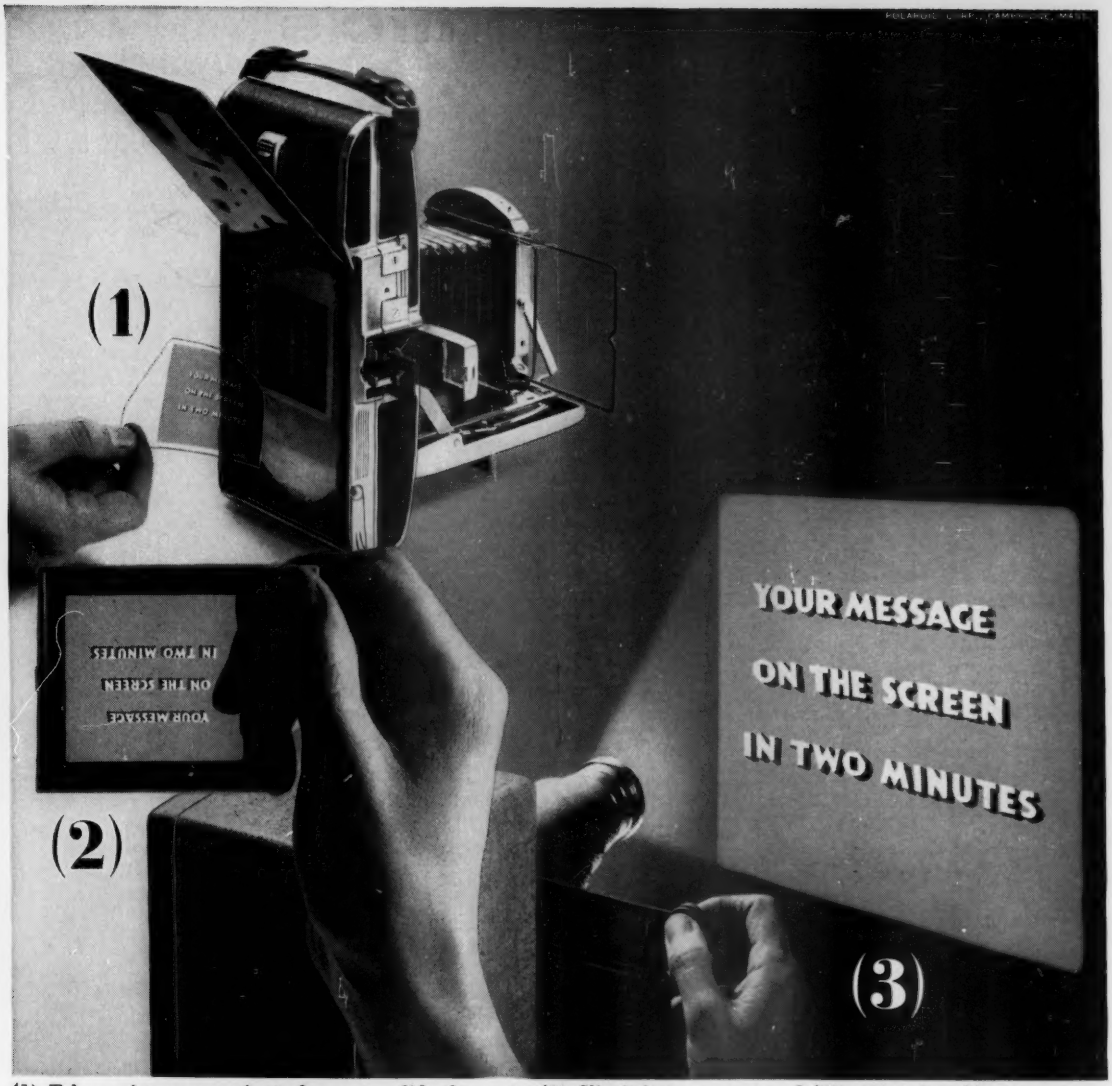

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(High gamma — low beta sensitivity)

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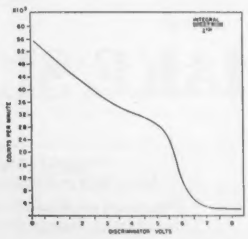
Over-all system stability permits separation of gamma emitters by use of precision pulse height selector to determine spectrum operating range. These features allow not only integral spectrum analysis but also the determination of useful gamma-pairs such as I^{131}-Cr^{51}, Fe^{59}-Cr^{51}, Co^{57}-Co^{60}, and Na^{24}-K^{42}.



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(High beta — low gamma sensitivity)

Use of a Type 811-7 Beta Well (completely interchangeable with type 810-20 well and type 810-21 solid gamma crystals) allows, for the first time, scintillation well counting of hard betas ($>$ 1 Mev) with *no source preparation* required.

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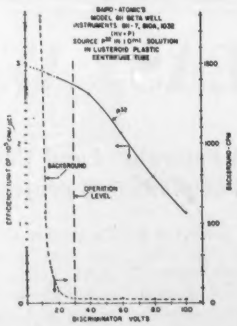

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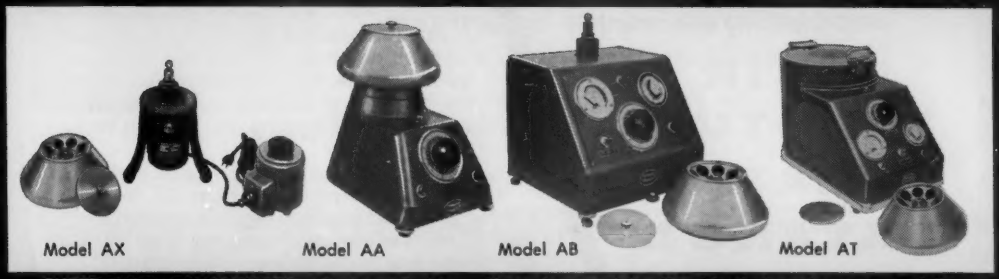

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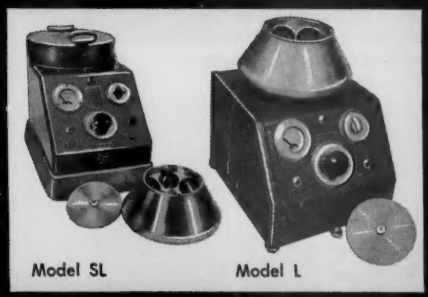

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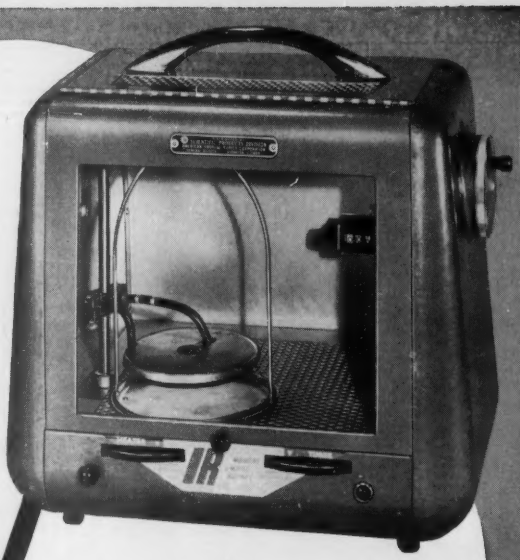

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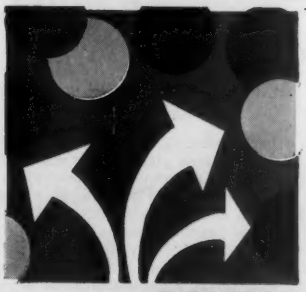

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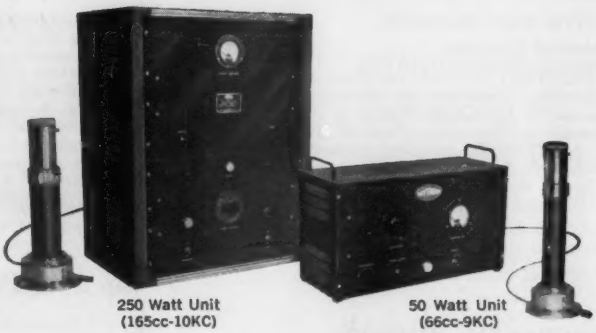

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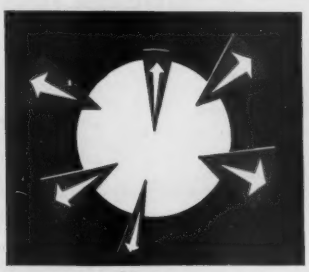

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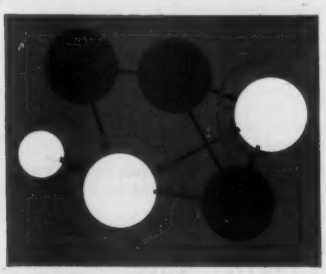

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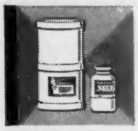

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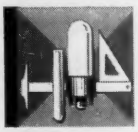

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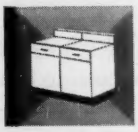

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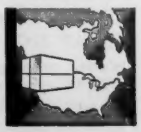

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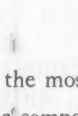

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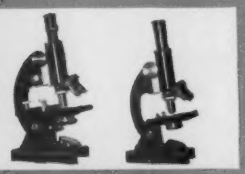

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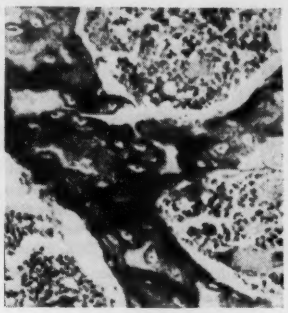

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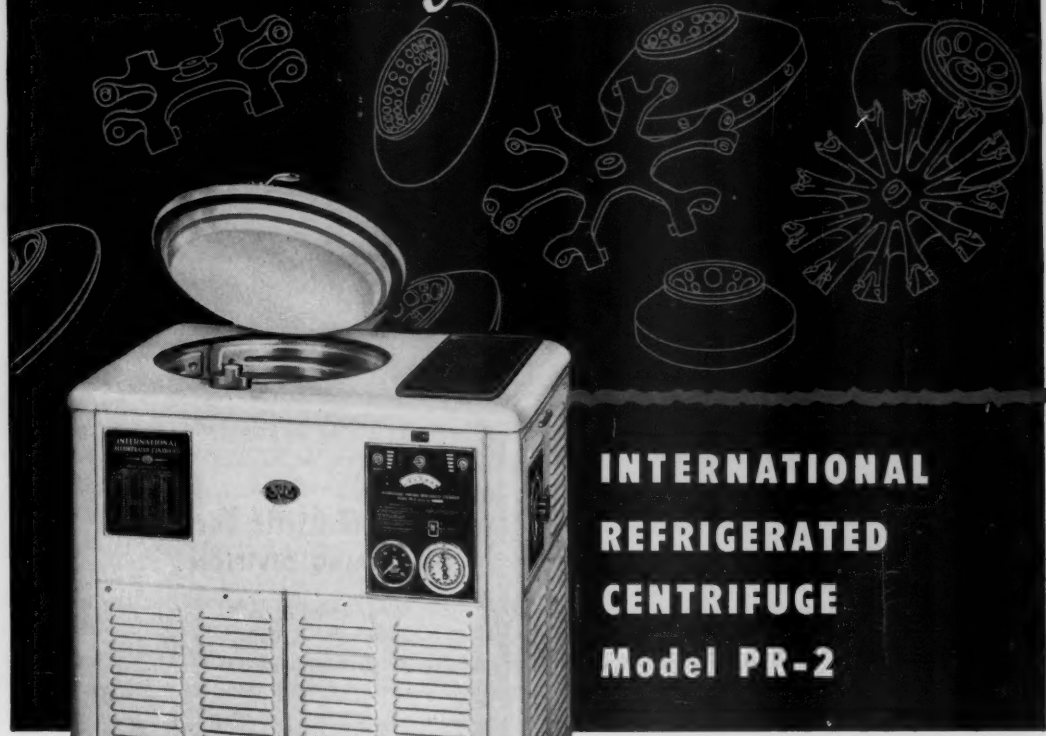

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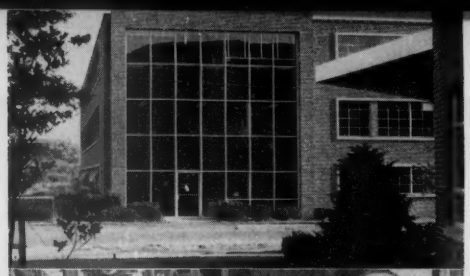

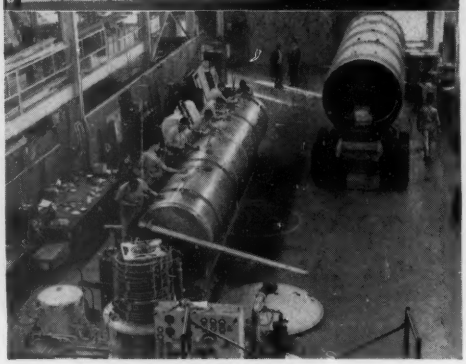

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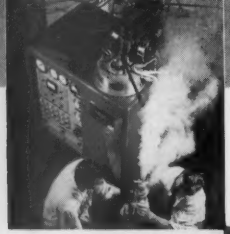

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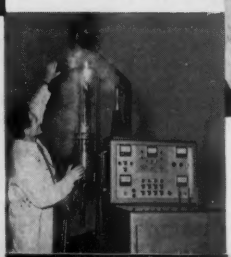

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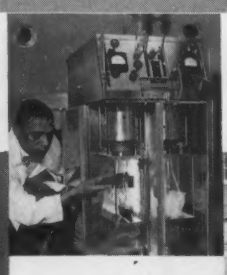

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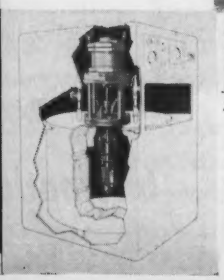

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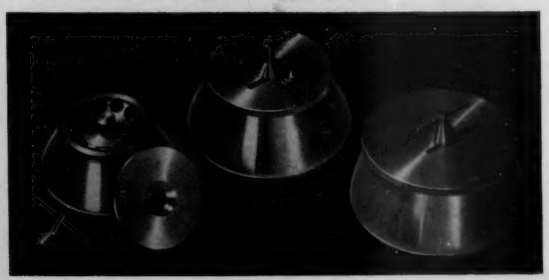

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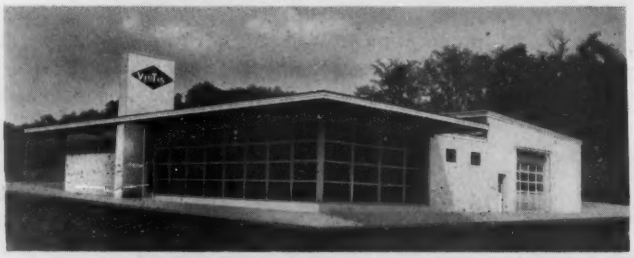

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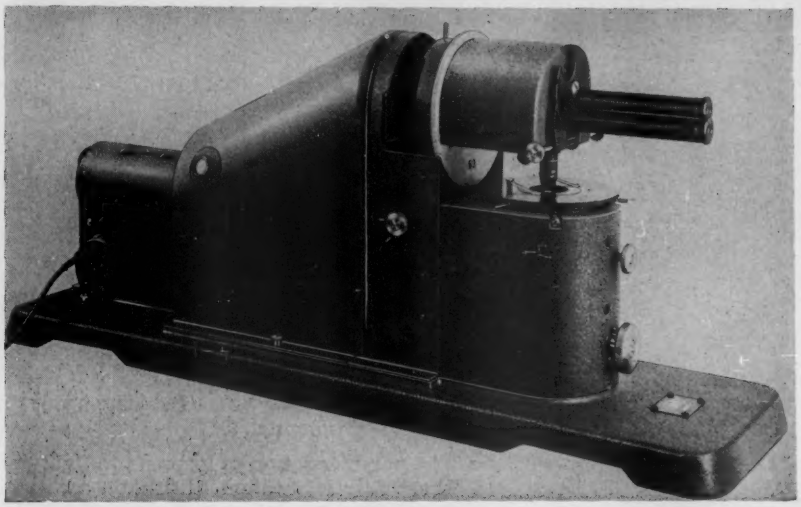

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- The military and peacetime uses of lithium metal in the field of heat transfer show great promise. Based on its low density, high heat capacity and high heat of fusion, lithium has no equal as a liquid metal coolant.
- Lithium metal is the starting material for the production of lithium hydride and, in turn, lithium amide and lithium aluminum hydride.
- Rocket and guided missile propellants utilize metallic "super-fuels." Many rely on complex compounds containing lithium metal or hydride. The key: lithium's tremendous reactivity.

Put lithium to work for you. Our bank of electrolytic cells can supply experimental grams or commercial tons of this admirably versatile metal. Write for details.

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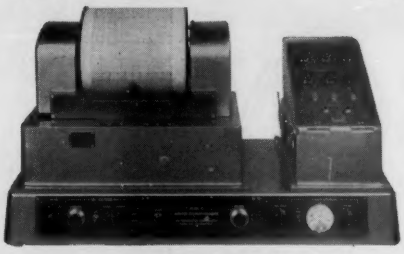
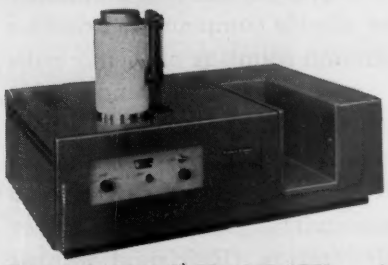
The Model 21

double beam recording infrared spectrophotometer

Leader in the infrared field, the Model 21 offers complete flexibility in spectral presentation, speed and resolution. Wavelength range from 800 millimicrons to 35 microns. New Model 321 available with double beam, double pass system.



P-E Analytical Instruments



The Infracord* Model 137

double beam recording spectrophotometer

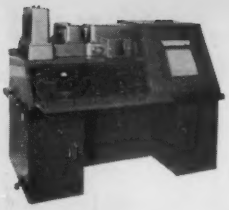
New low-cost infrared instrument for organic chemist and spectroscopist. Fast scan (2.5 – 15μ in 12 minutes), atmospheric and solvent compensation, differential analysis, instant wavelength reset, and linear wavelength vs transmittance recording. Records on notebook size paper. Handles spectroscopist's routine work.

Building Blocks and Accessories

Sources, monochromators, detectors with associated optics, electronics and control systems which may be assembled in many combinations. Covers infrared, visible and ultraviolet emission ranges completely.

Write us for literature on these instruments at

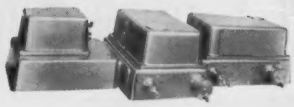
*Trademark



The Model 13U

universal spectrophotometer

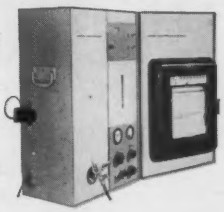
High performance in ultraviolet, visible, near IR and fundamental IR regions. Operates as a double beam, ratio recording or single beam instrument. Accommodates IR microscope.



The Model 112G

foreprism-grating spectrometer

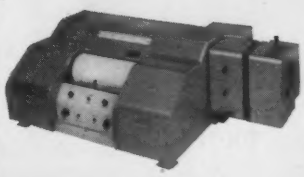
A very high resolution instrument with high energy per spectral slit width. Single beam, double pass operation. Less than 0.1% scattered light.



The Model 154C

vapor fractometer

A low-cost, vapor phase chromatography instrument capable of handling a wide range and high volume of chromatographic problems. Analyzes gases and liquids boiling up to 300°C. Available with reproducible gas and liquid sampling systems, fraction collection systems, integrators and a wide variety of column materials and sizes.



Spectracord* Model 4000

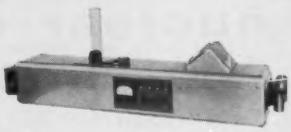
recording ultraviolet spectrophotometer

Features a double monochromator for high resolution and low scattered light (max. of 0.01% between 222 Mμ and 1.5μ). Covers visual, near IR and ultraviolet regions, records in transmittance or absorbance. Spectracord 3000 recording attachment converts most single monochromators to fast recording spectrophotometers.

The Model 146

flame photometer

Features prism monochromator, phototube detectors, internal standard or direct ratio operation. A self-contained instrument designed for speed and convenience of operation. Uses less than 5 cc of sample. Operates with any commercially available gas.



The Model 38A

Tiselius Electrophoresis instrument

Analyzes and separates complex solutions. Permits determination of identity, concentration and composition of solutes. Widely used by biologists, pathologists, biochemists.

INSTRUMENT DIVISION

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Simple . . . rapid . . . counts any sample in organic solvents and many water soluble compounds. Provides maximum counting efficiency with minimum background. Holds spurious counts to a negligible level. Attaches to any scaler having good high voltage stability. Requires no extra circuitry, gas tanks, regulator or refrigeration. (Refrigeration may be added for counting Tritium.) Its small size and economy makes it a laboratory convenience.

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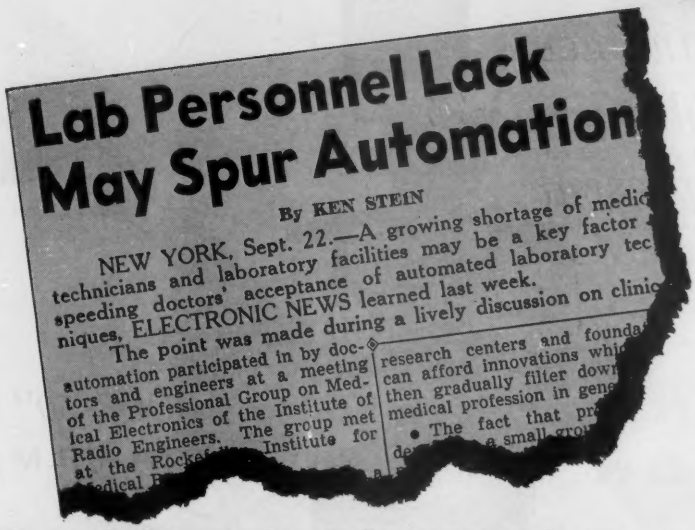

Lab Personnel Lack May Spur Automation

By KEN STEIN

NEW YORK, Sept. 22.—A growing shortage of medic technicians and laboratory facilities may be a key factor speeding doctors' acceptance of automated laboratory tec niques, ELECTRONIC NEWS learned last week.

The point was made during a lively discussion on clinic automation participated in by doc- tors and engineers at a meeting of the Professional Group on Med- ical Electronics of the Institute of Radio Engineers. The group met at the Rocke Institute for

research centers and founda can afford innovations whi then gradually filter down medical profession in gen

• The fact that pr de a small grou

The above headline appeared in a leading electronics trade paper over an article that described how automation may soon invade the medical laboratory to compensate for the lack of trained technicians. We here at Sorvall like to think that we have anticipated this need to some degree by our instrument research during the recent past. For instance, two unique SERVALL developments are:

SERVALL "SZENT-GYORGYI—BLUM" CONTINUOUS FLOW ATTACHMENT*

A unique development that allows the collection in one, two, four, or eight tubes, of small amounts of precipitate from large volumes of sample, at a flow rate of 200 ml per minute, *in one continuous operation.* Material from a reservoir is passed under controlled flow into the rotor tubes, the precipitate is separated, and the clarified supernatant is automatically removed. Extremely high speeds, up to 17,000 rpm when used with SERVALL'S Superspeed range of Centrifuges are permissible, and consequently sedimentation of the required sample is achieved in a fraction of the time taken by ordinary centrifuging. Modifications may be made to many existing SERVALL centrifuges in order to adapt them for Continuous Flow operation. SERVALL Superspeed Refrigerated Centrifuges now being produced are designed for accommodation of the "Szent-Gyorgyi—Blum" Attachment, **as is the all-new SERVALL Enclosed Superspeed Centrifuge.**

SERVALL SS-3 PUSH BUTTON AUTOMATIC SUPERSPEED CENTRIFUGE*

True automation for the medical laboratory, we should inform the electronics industry, is already here in the shape of the SS-3 Automatic Centrifuge. The SS-3 is the first centrifuge in the Superspeed range to incorporate automatic acceleration, pre-setting of desired speed, and dynamic braking, all on push-button actuation. In addition to these features, the unique SERVALL-Blum Gyro-Action Self-Centering Drive* make the SS-3 superior to anything ever before offered in Superspeed Centrifuges. Speeds in excess of 17,000 rpm provide a force of 34,400 x G. when a Superspeed Rotor is used; the large SERVALL Type GS Rotor may also be used in the SS-3, giving an operating capacity of 1,770 ml at speeds up to 9,500 rpm. The SERVALL Continuous Flow Attachment is available for the SS-3, thus developing the theme of automation for the medical laboratory even further.

SS-1 Superspeed Angle Centrifuge

SS-1A Superspeed Angle Centrifuge with Water Cooling

SS-2 Vacuum-Type Centrifuge

SS-3 Push-Button Automatic Superspeed Centrifuge (Patents Pending)

SS-4 Enclosed Superspeed Centrifuge (Patents Pending)

Superspeed Refrigerated Centrifuge

"Szent-Gyorgyi—Blum" Continuous Flow Centrifuge (Patents Pending)

Type GS Large Volume Rotor

Small and Medium Angle Centrifuges

Large Angle Centrifuges

Omni-Mixer (Homogenizer)

"Porter-Blum" Ultra-Microtome (Patents Pending)

Automatic Pipettes

Accessories including Centrifuge Tubes and Adapters

Since 1943, the World's Largest Manufacturer of Superspeed Centrifuges

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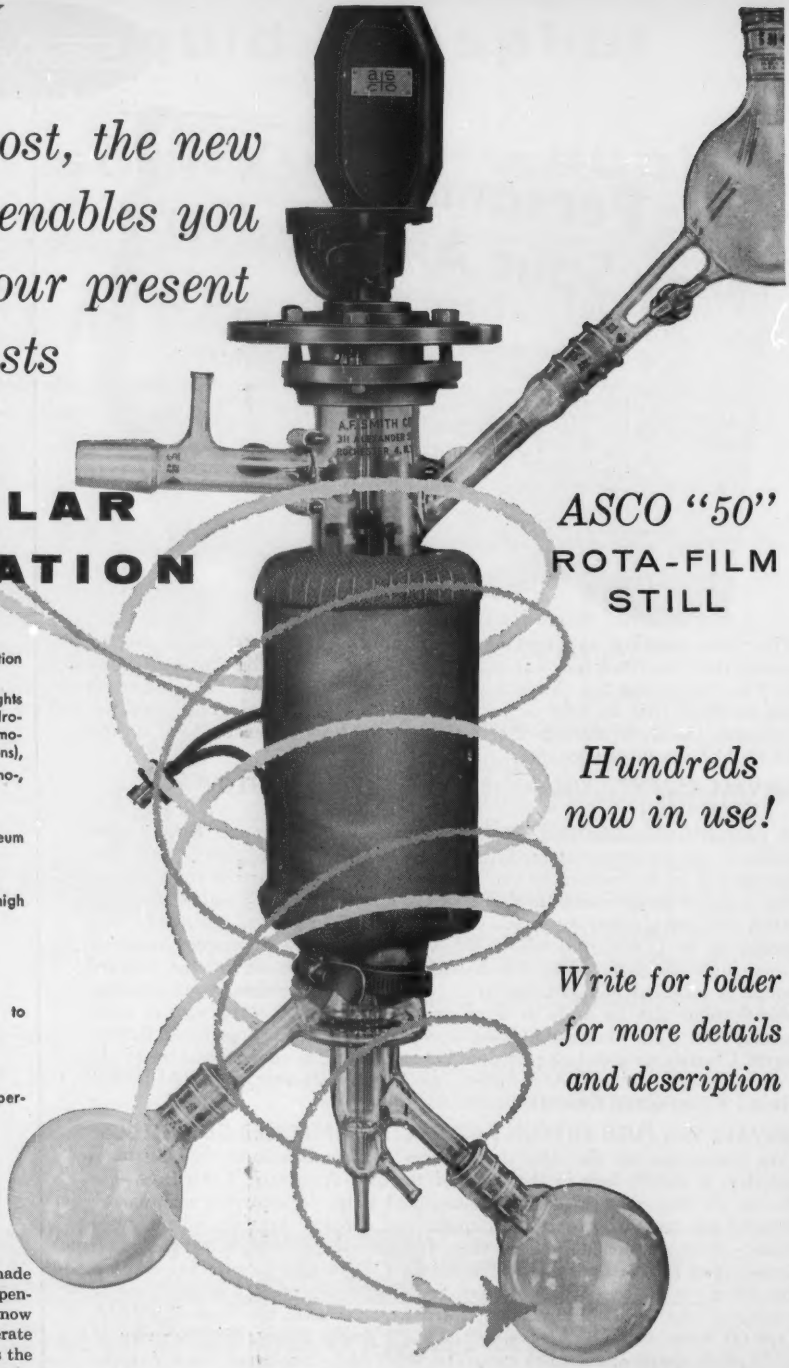

ASCO "50"
ROTA-FILM STILL

Hundreds now in use!

Write for folder for more details and description

With this simple-to-operate still you may...

- explore falling agitated film evaporation and distillation,
- distill materials with molecular weights ranging from 200 to 1250 weight (hydrocarbons) and some materials to 4000 molecular weight (silicones and halocarbons),
- deglycerinate and distill mixtures of mono-, di- and tri-glycerides
- distill tall oil
- distill paraffin from slack wax or petroleum residue
- deodorize oils,
- remove color bodies from materials of high molecular weights.

FEATURES

- Batches from 10 ml to 20 liters
- Vacuum range from atmospheric to 1 micron Hg.
- Temperature range to 450°C.
- Teflon or carbon rotor-wiper blades
- Stainless-steel (18-8 type 304) wiper-holders (Available with Hastelloy B)
- Continuous or batch feed
- All parts made of glass except wiper-holders and top plate
- UNITS MAY BE COUPLED FOR FRACTIONATION.

Fields of investigation heretofore made prohibitive through use of highly expensive investigative techniques can now be explored with this simple-to-operate molecular still. Since the "50" still is the laboratory counterpart of the large commercial Rota-Film Still, results obtained may be duplicated on a commercial scale of any magnitude.

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The instruments shown and described here are designed to provide the teacher, research worker or diagnostician with specialized equipment for every aspect of cardiac sound study: permanent graphic *recording* (2 channels); *group auscultation; high fidelity tape recording* and *playback;* and *visual monitoring.*

Each instrument design reflects the knowledge and incorporates the experience gained by Sanborn Company during forty years of precision medical instrument manufacture. Bulletins providing detailed performance data and specifications of each instrument are available on request.

complete HEART SOUND *instrumentation from* SANBORN

HEART SOUND TAPE RECORDER PLAYER
Sanborn-Ampex Model 278

A modern, versatile unit for listening, recording and playback of heart sounds, comprised of a Tape Transport (tape speed, 7.5 in/sec); Recording and Playback Amplifiers; a Dynamic Heart Sound Microphone and five Chest Pieces; and one Audiophone. The heart sounds heard, when the Sanborn "278" is used as either an amplifying stethoscope or as a playback device with recorded tapes, are not altered as compared to those heard with a good quality acoustical stethoscope. Furthermore, sound loudness can be controlled for maximum detection of faint sounds and murmurs. Monitoring of heart sounds, during recording, is done from the tape itself. In addition to recording and playback using 7" or smaller tape reels, the Sanborn-Ampex may also be used for repetitive playback of small loops of tape. Prerecorded teaching tapes, available from the American Heart Association, may also be played back with this instrument.

AMPLIFYING STETHOSCOPE
Model 256

An electronic amplifying stethoscope which permits the auscultatory sounds to be heard at any desired loudness by one or more observers. The sounds as heard possess exactly the same quality and character as when heard with a good acoustical stethoscope. Low-pitched or high-pitched sounds or murmurs may be accentuated, at the operator's discretion, by means of a set of five detachable microphone chest pieces. For listening by groups of up to 13, audiophones may be connected directly to the Amplifying Stethoscope; for groups of 20 to 30, supplementary junction boxes (and additional audiophones) are used; and for groups as large as 200 to 400 in amphitheaters or auditoriums, listening may be achieved by the use of permanently wired audiophone jacks.

For auditorium use, in place of multiple audiophones, the Model 263-100/200 Loudspeaker and Power Amplifier is available.

VISO-SCOPE
Oscilloscope Model 169A

When simultaneous visual presentation of heart sounds is desired, the Viso-Scope may be used in conjunction with any of the previous three instruments.* Waveform appears on the long-persistence 5" Viso-Scope screen as a sharply defined, bright yellow trace. This oscilloscope is extremely easy to operate, and is specially designed to be compatible with Sanborn recording instruments.

*With supplementary coupling units, write for details.

40th ANNIVERSARY 1917–1957 SANBORN COMPANY

TWIN-BEAM
Two-Channel Photographic Recording System

A high galvanometric deflection speed, photographic recording oscillograph for use in the simultaneous recording of the phonocardiogram and electrocardiogram; two of the electrocardiograph leads; or, of any two cardiovascular or physiological phenomena, with the use of applicable transducers.

It consists of (1) a recorder and output amplifier unit, with controls; and (2) two removable and interchangeable preamplifiers which provide for the simultaneous or separate registration of (a) electrocardiogram, or "pulse type" or slowly-varying inputs; and (b) phonocardiogram. Accessories furnished include one audiophone, one microphone with three open bells, and two Bowles diaphragm chest pieces.

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DETERMATUBE™

A NEW CONCEPT IN CLINICAL CHEMISTRY!

Lyophilized, single assay, reagent tubes for determination of serum *TRANSAMINASE, URIC ACID and LACTIC ACID DEHYDROGENASE*

ACCURATE SIMPLE LOW-PRICED

(merely add water, serum and read)

Although developed for use with a spectrophotometer, **a spectrophotometer is not necessary** for Transaminase or LDH Determinations. The tubes may be used as cuvettes in the, low priced **COENZOMETER** (pat. pending) which measures absorption at 340μ. This instrument is currently being introduced by Macalaster Bicknell Company, 243 Broadway, Cambridge, Mass.

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THE NEW, RAPID MICRO METHOD OF GLUCOSE ANALYSIS

REQUIRING NO DEPROTEINIZATION or HEATING

Based on the coupled enzyme system of glucose oxidase and peroxidase, the reaction is specific for glucose.

A blood glucose can be obtained in 11 minutes using 0.1 ml. serum or plasma. A photoelectric colorimeter is the only piece of special apparatus necessary. Simply add serum to reagent and read color in minutes.

With proper precautions, the method is suitable for urine glucose determinations.

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Type: Master, Plane Reflection.

Size: Blank 6" diameter.
Ruling 5" wide x 2.8" long.

Lines per inch: 14,400.

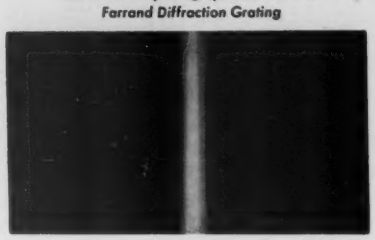
Efficiency: 65-85% of Incident Energy in Blazed Region.

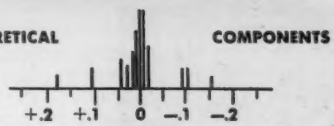
Ghost Intensity: Less than 0.1% in First Order of 5500 Å.

Resolution: 100% of Theoretical in Third Order or Better.

HYPERFINE STRUCTURE OF MERCURY SPECTRUM

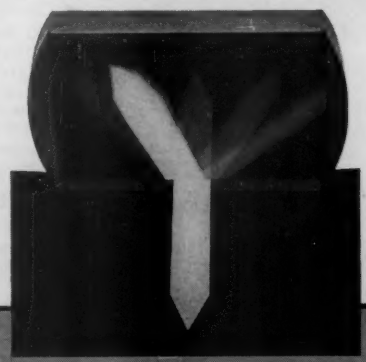
Unretouched photograph taken with a Farrand Diffraction Grating





λ=4538 A 6th ORDER (DOUBLE PASS)
RESOLVING POWER=750,000

Below, an unretouched photograph of a grating, blazed for First Order at 5500 Å, illustrates the control achieved over the groove form.



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The Farrand Optical Co., Inc. is also in a position to supply the FARRAND-STRONG Ruling Engine on special order

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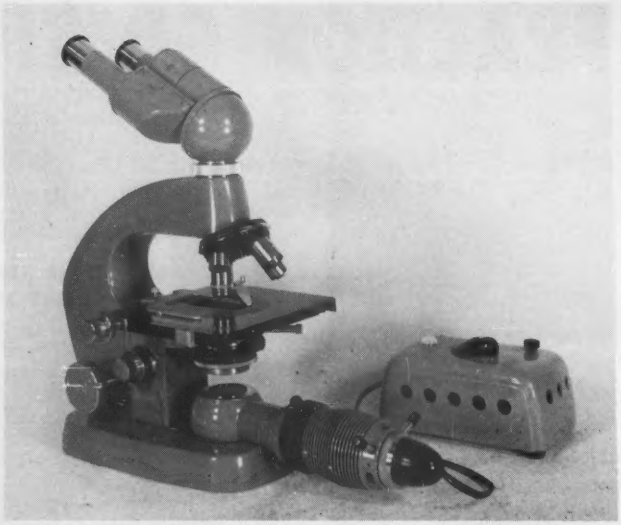
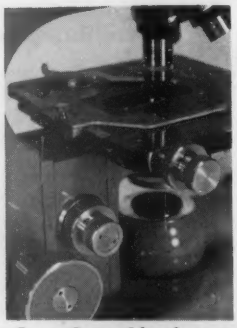
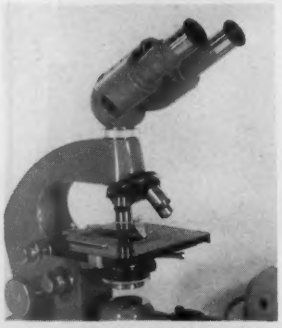
OLYMPUS
MICROSCOPES



New Olympus Research Microscope Model DX



Stage Control knobs very conveniently located



Binocular Head is Reversible

The Olympus Optical Company of Japan, with many years of experience in the manufacture of fine microscopes, has again demonstrated its excellent technical ability in the production of a totally new research microscope.

The following features make Olympus Model DX Research Microscope outstanding in its field:

- **Proper inclination and height of binocular head makes it most comfortable to use.**
- **Quadruple nosepiece is spring-loaded for protection of slides.**
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- **Excellent light source with centering device. Transformer and rheostat for light intensity control.**
- **OPTICS**
  Eyepieces: Paired P7X, P10X, P15X and K20X
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  Magnifications: 28X–2000X
- **Available accessories: Darkfield condenser, phase contrast, inclined monocular tube, photographic tube, and fluorite objectives.**
- **Price only $690.00**

There are many other types of Olympus microscopes to meet nearly every requirement of microscopy. We can save you from 30%–50% on your microscope costs.

All Olympus microscopes carry a three-year guarantee against defective materials or workmanship.

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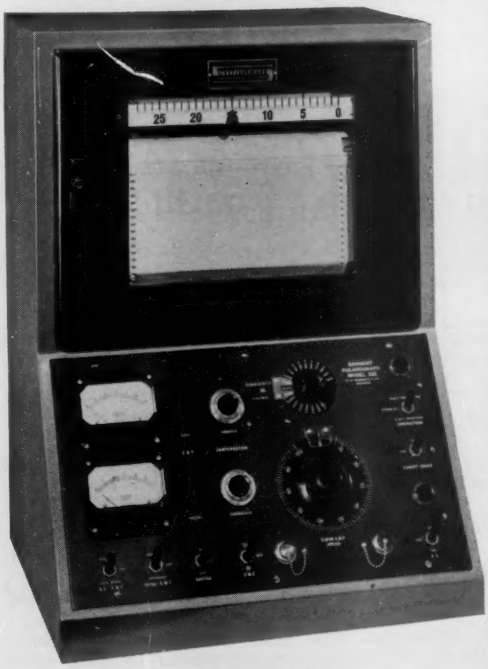

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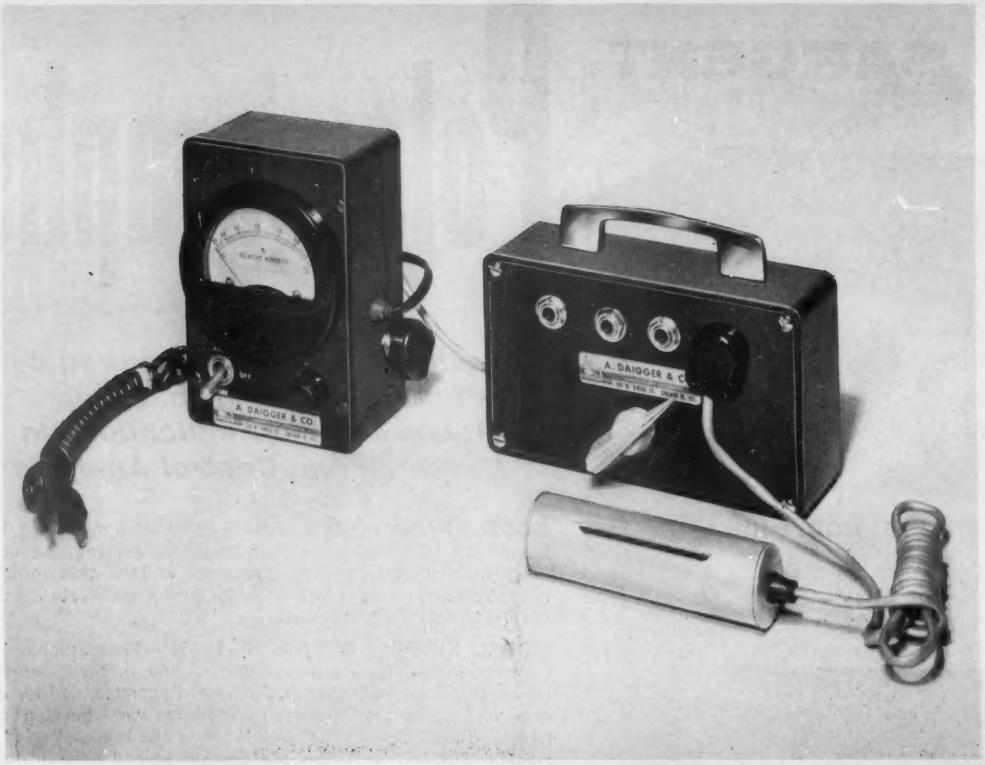

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REMOTE READING INSTANTANEOUSLY REACTING ELEMENT

A new instrument, our electronic humidity gauge, incorporates the latest in electronic devices into an age old device representing a real advancement in the design of humidity gauges. This gauge is really an electronic instrument, and places humidity indication within the field of instrumentation for the first time, by converting relative humidity into electrical energy.

The DAIGGER gauge relates moisture to the resistance of a transistorized electronic circuit producing instantaneous reading on a scale calibrated directly in per cent relative humidity.

Remote reading is possible up to 1000 feet. Because of the portability of the sensor and its electronic response the instrument is extremely convenient even in inaccessible areas. This should make the instrument of interest to anyone working with radiation problems or poisonous materials.

Whenever control and measurement of humidity is essential in chemical processes and in many biological techniques, this new electronic humidity gauge will prove of value.

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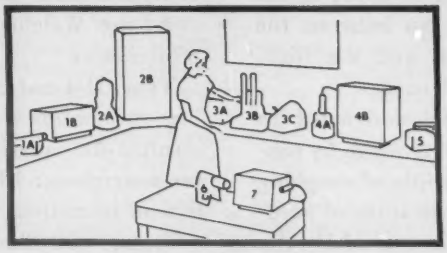

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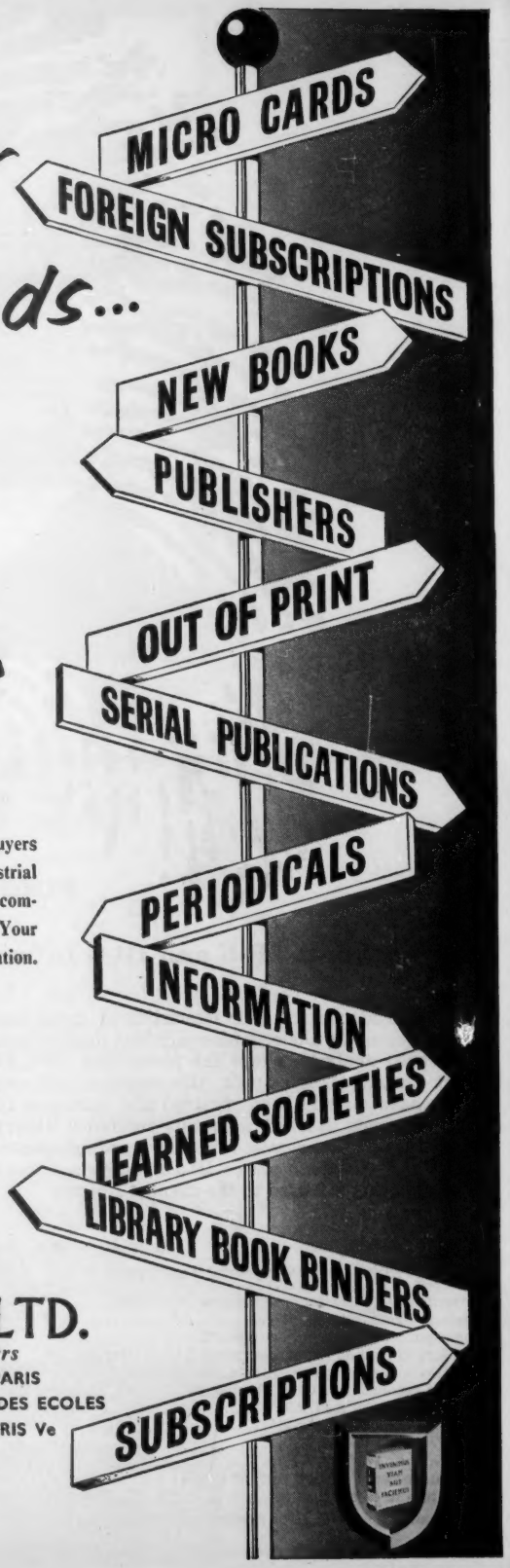

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Meeting the Challenge

It would be nice if the superlative feat of building an artificial moon to circle the earth were a matter only of scientific significance. Then, aside from proper honors to the responsible scientists and engineers and to the country that made their work possible, interest would center on the data to be contributed to the International Geophysical Year. But, under the circumstances of a continuing threat to our efforts to preserve world peace, the fact that the first space satellite was made in the Soviet Union and not in the United States becomes an important, perhaps a dominant consideration.

Whatever the historical causes, the pervasive impression in this country has been that in science, and especially in something called "know-how," the Soviet Union plays follow-the-leader to the more industrialized Western nations. At one level, we like to dwell on such items as the latest Russian cars, which, down to the very emblem of manufacture, look like nothing so much as American models of several years ago. At another level we like to think of Soviet espionage as Russia's principle source of new scientific knowledge. At a third level, we like to think about Lysenko.

This impression has needed correction, and its holders have now had a rude awakening in a completely convincing demonstration of the excellence of Russian science and technology. The extent of the Soviet lead in those parts of physics, chemistry, metallurgy, and electronics that bear on rocket technology is not publicly known; it may or may not be known to our intelligence officers. But one piece of evidence was up in the sky on 4 October 1957 for all to see and hear. Of course, not all Americans needed this demonstration. Mathematicians, experimental scientists, and engineers who have visited Russia in recent years have come home with complimentary accounts of what they saw.

The success of the American response to the challenge implied by Soviet science and technology will be measured by something much more fundamental than the speed with which this particular feat is matched. Both the U.S. and the U.S.S.R. are capable of great achievement, but neither is capable of simultaneous supremacy on all fronts. In the military sphere, the tremendous cost of developing new weapon systems places an all-encompassing defense program beyond our means. Selection is essential. Our hope is that, if we cannot do everything in the way of conventional weapons, advanced weapons, and ballistic missiles, we can find the wisdom to select the right points at which to apply the full measure of our strength.

There are various means in this country by which the executive and legislative branches of the government come to decide upon our best bets in allocating finite resources among competing needs. The use of scientist and engineer advisers in making some of these decisions will certainly increase, as will public attention to matters of science education and research support. It is not to our credit that these changes will come about as a result of Russian success, but it will be to our benefit if scientists and government administrators learn better how to work together in the grim gamesmanship of international diplomacy.—J. T.

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Ultraviolet Television Color-Translating Microscope

V. K. Zworykin and Fred L. Hatke

Every advance in microscope technique has been followed by comparable strides in biology and medicine. This has been true of the introduction of the light microscope, of the spectroscope, and of the electron microscope. We can thus hope that the ultraviolet television color-translating microscope, which adapts color vision to the viewing at high magnification of living cells illuminated by ultraviolet radiation, may also make a material contribution to biological research.

It is well know that the chemical constituents of unstained living cells, though practically transparent to visible light, exhibit strong characteristic absorptions in the ultraviolet, particularly in the range from 2200 to 3000 angstroms (*1*). Thus, the recognition of structure in cells and tissue specimens is greatly facilitated by studying them under ultraviolet illumination. In the past, ultraviolet microscopy has suffered from the drawback that photographic exposure and development was required to render the ultraviolet image visible. This difficulty was removed by the development of the ultraviolet television microscope, which permits the immediate and continuous observation of the specimen under ultraviolet illumination (*2, 3*).

The ultraviolet television microscope, like the photographic ultraviolet microscope, yields a simple monochromic representation of the specimen, in which the half tones correspond to the relative over-all absorption of different portions of the specimen for the illuminating radiation. Brumberg (*4*) recognized at an earlier date that considerably more useful information would be conveyed by a color representation of the object, in which the relative intensity of the three primary components—red, green, and blue—would be proportional to the transmission (or absorption) of the specimen at three selected ultraviolet wavelengths. If the wavelengths are chosen to correspond to the characteristic absorptions of specimen constituents of particular interest to the observer, this procedure makes optimum use of trichromatic vision to discriminate between the constituents.

Brumberg's idea was rendered practical for photography through the development of catadioptric microscope objectives (*5–7*) which were apochromatic over the entire range of the ultraviolet and visible spectrum (2200 to 8000 angstroms). With these objectives, Land and his coworkers (*8*) were able to construct a photographic color-translating microscope which yielded excellent color pictures of biological specimens under ultraviolet illumination. In Land's system, three film frames were exposed successively to the images of the object formed by ultraviolet radiation of three different wavelengths as delivered by a grating monochromator. These frames were developed, fixed, and washed in a high-speed developing system and then projected through the correlated red, green, and blue filters in superposition on a common viewing screen. Both negative representation, in which the intensity of a given color corresponded to the absorption of radiation of the correlated wavelength, and positive representation, in which the intensity corresponded to the transmission of the same radiation, were studied. The most effective correlations are shown in Table 1.

A color-translating ultraviolet microscope which follows Land's instrument in its main outlines has been marketed by the Scientific Specialties Corporation (*9*). Negative representation is employed. Photographic processing demands only 25 seconds; hence, the delay between exposure and examination of the picture is minimized. The exposure time for the three selected wavelengths is adjusted automatically to compensate for differences between the light output of the monochromator and that of the source, a water-cooled, high-pressure mercury arc.

As has already been indicated, some very good results have been obtained with the photographic method. Nevertheless, this method has certain obvious shortcomings. The most important of these is the impossibility of scanning large quantities of material at high speed for the detection, for example, of abnormalities or features of special interest. Under such circumstances, a delay of half a minute between the viewing of adjoining microscopic fields would seem to be prohibitively long. Furthermore, although the obtaining of a permanent photographic record of interesting specimen fields may be deemed an advantage, the necessity of obtaining such a record for every field examined is the opposite, both from the point of view of economy and from that of swamping the interesting material with records of little value.

It is the aim of the ultraviolet television color-translating microscope to overcome these drawbacks by providing an instantaneous color representation of the specimen. With it, the examination of specimens in the ultraviolet can be carried out with the same speed and simplicity as examination in the visual range. Whenever a permanent record is desired, it can be obtained by color photography of the receiver screen (*10*).

Construction

The basic plan of the several types of television color-translating microscopes which we have constructed is shown in Fig. 1. A microscope with reflective condenser and objective projects the image on the photosensitive target (or targets)

Dr. Zworykin is an affiliate member of the Rockefeller Institute for Medical Research, New York, and honorary vice president of the Radio Corporation of America and technical consultant to the RCA Laboratories in Princeton, N.J. Mr. Hatke is an electronic engineer on the staff of the Rockefeller Institute for Medical Research.

of a television camera, whose video signal is employed for the reproduction of an image of the specimen on the screen of a color receiver. Illumination is provided by a pulsed light source incorporating one or several monochromators and so arranged that radiation of the three selected ultraviolet wavelengths falls on the specimen at successive pulses. The pulse source also controls the vertical deflection in the camera and receiver in such fashion that the pulses of illumination occur during vertical fly-back time, the picture signal stored by a radiation pulse of a particular ultraviolet wavelength being utilized for generating a component picture of the corresponding color in the succeeding frame period.

The feature of the sequential illumination of the specimen with ultraviolet radiations of different wavelength is common to the several instruments described in this article. Sequential illumination is to be preferred to the alternative of illuminating the specimen with unseparated, "white," ultraviolet radiation and effecting the separation subsequently by beam splitters or filters, or both, since it reduces the total exposure of the specimen to ultraviolet radiation and thus minimizes the chemical and biological changes effected by this exposure. Apart from this, there is considerable choice in the design of both the illuminating system and the camera.

The camera tube may, in principle, employ either a photoconductive or a photoemissive target. The photosensitive material must, of course, maintain high response throughout the portion of the ultraviolet spectrum utilized and must be deposited on a base which is transparent to ultraviolet radiation. The experimental ultraviolet-sensitive Vidicon, employing a photoconductive layer of amorphous selenium (*11*), which has been developed specifically for research applications, is particularly attractive since it combines a quantum yield of the order of 1 in the ultraviolet with simplicity of operation and compactness; it is interchangeable with the standard Vidicon employed in commercial industrial television equipment. Its spectral response is shown in Fig. 2.

Table 1. Most effective correlations between color and wavelength in negative and positive representation.

Ultraviolet wavelength (A)	Representation	
	Negative	Positive
2650	Green	Blue
2850	Red	Green
3150	Blue	Red

Table 2. Values of n, χ, and Δd at selected wavelengths for a lens of focal length of 4.5 inches.

λ (A)	n	χ	Δd (in.)
2537	1.5980		−0.210
3130	1.5737	69°4.5′	0
4358	1.5540		0.170

The ultraviolet-sensitive Vidicon exhibits a certain amount of lag—that is, the charge pattern on the target excited by exposure to radiation is not removed completely in a single scan, but persists for a fraction of a second, giving rise to after-images of rapidly decreasing intensity. Wherever this slight carry-over from one frame to the next is harmful, it becomes advantageous to employ a camera tube effectively free from lag, such as the image orthicon. Experimental image orthicons with ultraviolet-transmissive front ends and photocathodes of high sensitivity in the ultraviolet (Fig. 3) have been built to order for the television color-translating microscope. Their performance has been very satisfactory. At the same time, the higher cost and more complex auxiliary equipment demanded by these tubes makes it clearly desirable to use them only when freedom from lag and very high sensitivity are essential requirements.

The illuminating system of the color-translating microscope may employ either a single light source or three light sources. Similarly, the camera may operate on the field-sequential principle, employing a single camera tube, or on the simultaneous principle, employing three camera tubes in parallel. The first television color-translating microscope, constructed at the RCA Laboratories in Princeton, New Jersey (*3*), used a single pulsed light source and single Vidicon camera tube. A simple mechanical system was employed to select in turn radiation of three different wavelength ranges for illumination of the specimen.

The method of wavelength selection was based on the fact that the focal points for a prism monochromator with uncorrected collimator and telescope lenses made of the same material as the prism lie along a straight line which is oblique to the direction of the refracted pencils. If the entrance slit of the microscope illuminator is placed on this straight line, a plane mirror perpendicular to the line will project the focal point for radiation of different wavelengths onto the slit as it is displaced in a direction perpendicular to its surface.

Figure 4 shows the application of this principle. A medium-pressure mercury arc lamp illuminated the entrance pupil of a 60-degree quartz prism monochro-

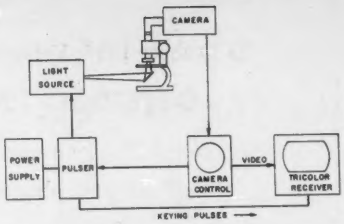

Fig. 1. General block diagram of television color-translating microscope.

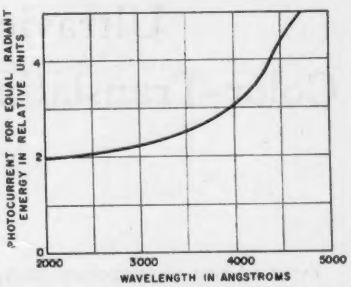

Fig. 2. Ultraviolet response of experimental ultraviolet-sensitive Vidicon.

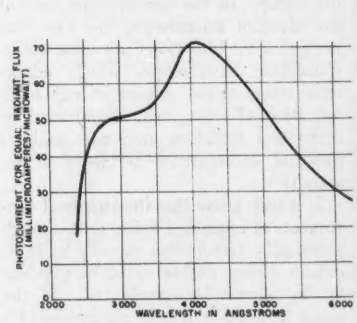

Fig. 3. Ultraviolet response of experimental ultraviolet-sensitive image orthicon.

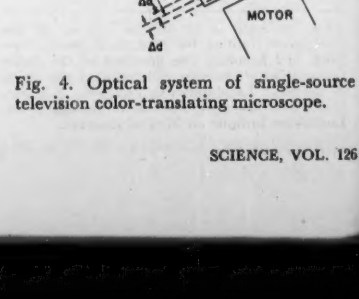

Fig. 4. Optical system of single-source television color-translating microscope.

mator provided with quartz collimator and telescope lenses, all cut perpendicular to the optic axis. The mirror M consists of a rotating disk with three sectors, recessed by different thickness differences Δd. For a 60-degree prism, it may be shown that the glancing angle χ formed at the mirror surface by the principal ray of radiation for which the index of quartz is n is given by

$$\tan \chi = \frac{\sqrt{4 - n^2}}{n - 1}$$

Furthermore, the relative displacement of the mirror surfaces is given by

$$\Delta d = - F \frac{n}{n - 1} \sqrt{\frac{5 - 2n}{4 - n^2}}$$

where F is the focal length of the collimator and telescope lenses for the median wavelength. Thus, for a lens focal length of 4.5 inches, we obtain the values shown in Table 2 for a system employing 2537, 3130, and 4358 angstroms as the selected wavelengths.

The monochromator tube, synchronous drive motor, sector disk, and microscope are shown in Fig. 5. The disk was rotated at one-third the frame frequency of the television system. Automatic phasing of the television system could be achieved by deriving a triggering signal for the vertical deflection from the interruption of a light beam falling on a photocell by the rotating disk. The signal levels for the three wavelength ranges were balanced empirically by masking the mirror sectors.

Although the principle of color translation could be readily demonstrated with this instrument, it had several shortcomings. Perhaps the most obvious of these was the difficulty of changing the wavelength selection. Every change in wavelength demanded the insertion of a new sector mirror or plane parallel shim to adjust the height of the mirror surface. Furthermore, the fact that the angle of incidence of the illumination varied slightly with the wavelength made it very difficult to achieve color balance over the entire field. Finally, the lag of the experimental Vidicon employed in the instrument prevented the attainment of highly saturated colors.

These and other drawbacks were overcome in a more elaborate television color-translating microscope constructed at the Rockefeller Institute for Medical Research in New York. The illuminating system of this instrument is shown in Fig. 6. Three Farrand grating monochromators with individual pulsed light sources permit arbitrary adjustment of the illuminating wavelengths by means of the calibrated knobs on the front panel. The cover for one of the sources, a Hanovia 10B1 quartz mercury arc lamp, is removed in the illustration. The use of separate light sources has the incidental advantage that sources can be selected for high emission in particular wavelength ranges. Thus, for the shortest wavelengths, a Hanovia 250-watt xenon-mercury lamp is employed.

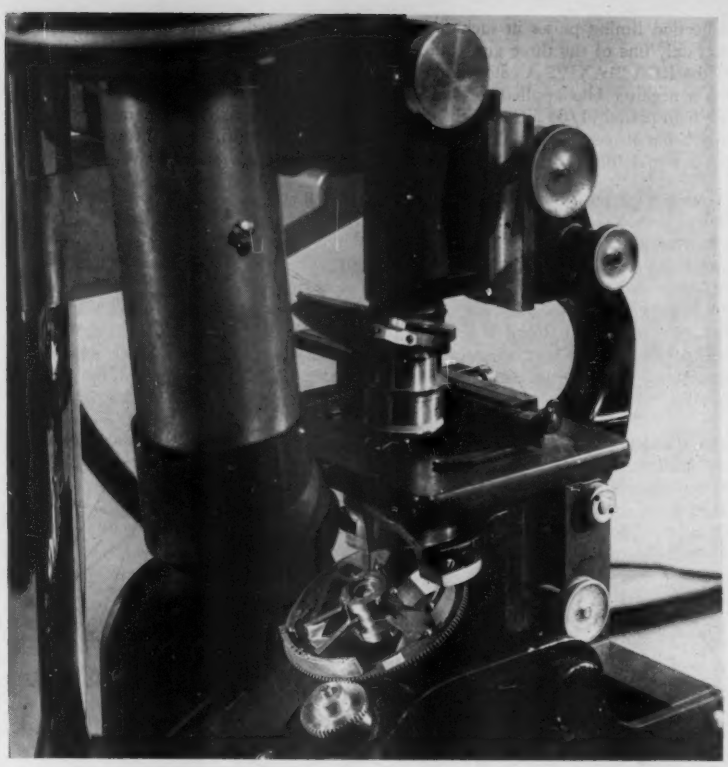

Fig. 5. Detail of single-source television color-translating microscope (RCA Laboratories).

The optical arrangement of the illuminator is more clearly evident from the diagram in Fig. 7. The source is imaged by a quartz lens on the entrance slit of the monochromator, and the exit slit is imaged by a second lens onto the center of a rotating 45-degree mirror which directs the illuminating radiation into the microscope substage, an $f/3.5$ aperture ratio being maintained throughout. The amplified vertical pulses from the synchronizing generator of the television system are applied through contact brushes on slip rings attached to the mirror stage to the three thyratron circuits feeding the light sources in succession, triggering a light flash at the instant when the principal ray from the monochromator and the normal to the rotating mirror surface lie in a common vertical plane. Synchronism between the mirror rotation and the synchronizing generator is assured by deriving control signals for the synchronizing generator from the mirror stage commutator. Fine adjustments of the monochromators make it possible to make the mechanical phase differences for the three illuminating units precisely 120 degrees.

The circuit arrangement for sequential camera operation, with a single camera tube, is shown in Fig. 8. The output signal of the camera is applied in parallel to the red, green, and blue video amplifiers of the color receiver. However, a set of three bistable multivibrators connected in a ring are driven by vertical-

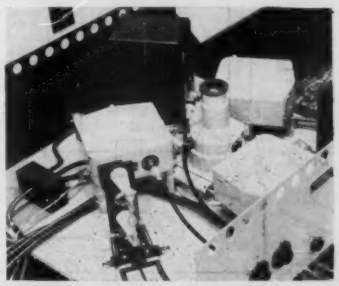

Fig. 6. Illuminating system of television color-translating microscope with three separate sources (Rockefeller Institute).

deflection timing pulses in such fashion that only one of the three gun cathodes of the RCA 21AXP22-A color kinescope has a negative bias applied to it in any one field period (1/60 second), the other two being driven to cut-off. Thus, the video signal for successive fields modulates the red, green, and blue scanning beams in turn, in such fashion that a component picture of a particular color is generated in the field period following the exposure of the camera tube target to an image formed by ultraviolet radiation of the correlated wavelength.

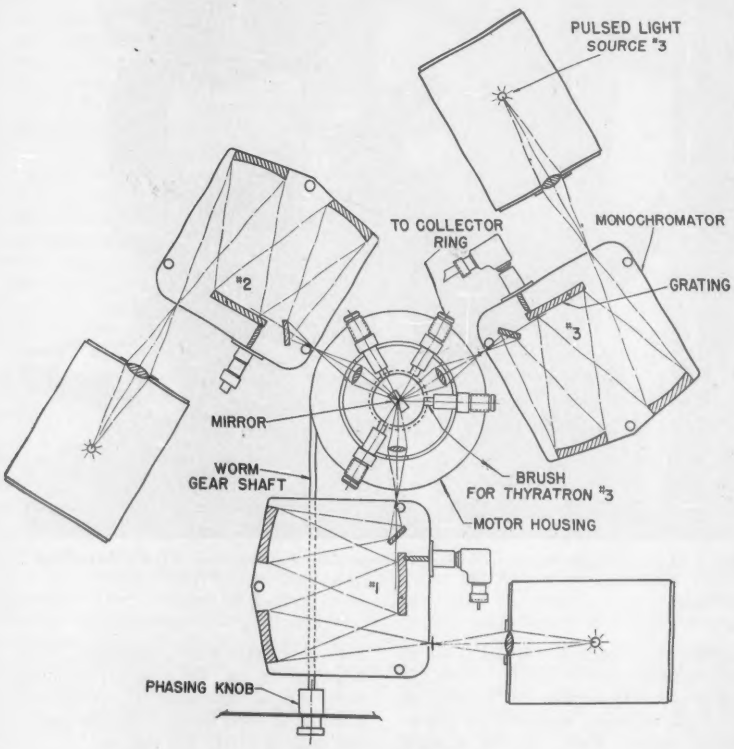

Fig. 7. Illuminating system.

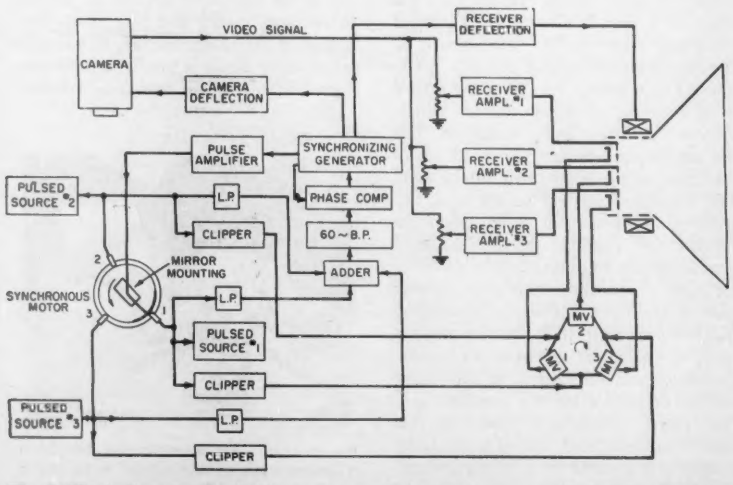

Fig. 8. Block diagram of television color-translating microscope at Rockefeller Institute for Medical Research.

Timing control for the entire system is provided by the commutator sector mounted on the rotating stage for the 45-degree mirror. This sector is connected both to a direct-current source and to a pulse amplifier deriving sharp timing pulses 1/60 second apart from the synchronizing generator. Thus, a narrow pulse riding on top of a broad square pulse is applied, in 1/20-second intervals, to each of the brushes. This signal is divided three ways. For timing control, the signal is passed through low-pass filters which remove the spike and smooth the square pulses, after which it is added to the similarly smoothed outputs of the other two brushes. A band-pass filter selects the 60-cycle component of the sum, which is phase-compared with the vertical synchronizing pulses delivered by the synchronizing generator. The output of the phase comparator is then employed to lock the synchronizing generator to the rotation of the 45-degree mirror.

A second current path from the brushes contains a clipper, which clips off the narrow timing pulses and applies them to the appropriate junction between a pair of the multivibrators, gating the beam currents in the color kinescope.

The third path provides the triggering pulses for the ultraviolet source circuit, which is shown schematically in Fig. 9. A 12-kilovolt pulse for starting the lamp is obtained from a sawtooth generator and an output tube feeding into an autotransformer. In addition, the synchronizing pulse is amplified and applied to a thyratron grid to provide a low-impedance path for a condenser discharge through the lamp. Finally, a low-voltage "keep-alive supply" maintains continuous current through the arc lamp. Thus the ionization within the arc lamp is maintained above a certain minimum level, thereby stabilizing the position of the arc and eliminating random delays between the discharge through the lamp and the application of the trigger pulse.

A view of the complete television color-translating microscope is shown in Fig. 10. The optical microscope, the image orthicon camera, and the black-and-white test monitor are mounted on a desk, whose central drawer space contains the illuminating system. Power supplies are housed in the drawer space to the left. The color monitor is a modified RCA color receiver.

The objective and the substage condenser of the microscope are identical catadioptric objectives corrected for different thicknesses of quartz; all the remaining lenses of the illuminating system are simple quartz lenses maintaining an $f/3.5$ aperture ratio. The slit image in the plane of the 45-degree mirror is imaged by a pair of these lenses into the

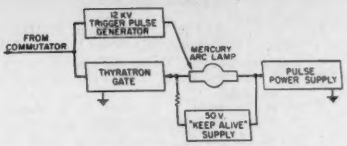

Fig. 9. Ultraviolet-source circuit.

entrance pupil of the substage condenser, which, in turn, images one of the lens surfaces in the specimen plane. With this arrangement, the illumination sweeps across the image plane as the 45-degree mirror is rotated. Thus the precise phasing between the light flashes and the mirror position afforded by the described circuits is essential for realizing color balance throughout the image field.

Performance

Within the short period during which the instrument has been in use, it has been applied to the study of a number of simple preparations, all of them unstained and unfixed. The possibility of studying living materials at high magnifications, without the introduction of artifacts resulting from chemical interference, may be regarded as one of its primary advantages. Protracted studies of tissue specimens—for example, mouse connective tissues—have revealed no visible structural changes resulting from the ultraviolet irradiation employed; paramecia, tetrahymena, and amebas, similarly, showed no change in behavior or motility, whereas ameboid slime-mold cells tended to be immobilized after about 2 minutes of irradiation at 2650 angstroms, and rotifers exhibited a definite negative tropism.

Cell preparations frequently reveal fine details, such as "chromatin" granules in protoplasm, which are not visible with illumination by visible light. The major absorptions are generally due to nuclear or protein materials, so that, in many preparations, only nuclei appear strongly colored. In addition, pigments such as hemoglobin or chlorophyll, present in too small concentrations to impart appreciable coloration to a specimen, give rise to striking color contrasts in the ultraviolet color-translating microscope; thus the streaming of protoplasm and cyclosis of chloroplasts become readily visible.

Particular chemical compounds with characteristic ultraviolet absorptions are readily detected by correlating critical ultraviolet wavelengths with the primary colors. Knowing the absorption coefficients of the materials in question, we can even obtain quantitative estimates of their concentrations at any point of the specimen. For this purpose we employ a line-selecter oscilloscope to select a particular horizontal scanning line and represent the variation of the video signal along it in the red, blue, and green channels on separate cathode-ray tubes. This is illustrated in Fig. 11, which shows a nucleated red cell of frog blood. In the original picture, photographed from the color monitor, the nucleus appears orange, the hemoglobin, yellow, and the white corpuscles, purple. A white line through the center of the red blood cell indicates the location of the selected line. The three oscillograms show the variation of the video signal for the three selected ultraviolet wavelengths and thus give an indication of the concentration of the principal absorbing materials along the selected line. Quantitative measurements by this means would of course require density step-wedge calibration.

The fact that, in the television color-translating microscope, practically any chemical differences can be translated

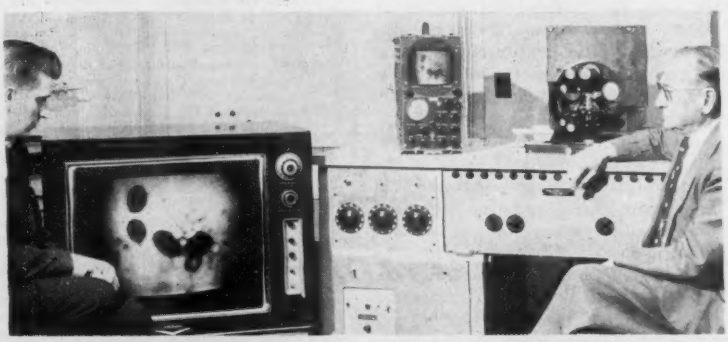

Fig. 10. Complete television color-translating microscope (Rockefeller Institute).

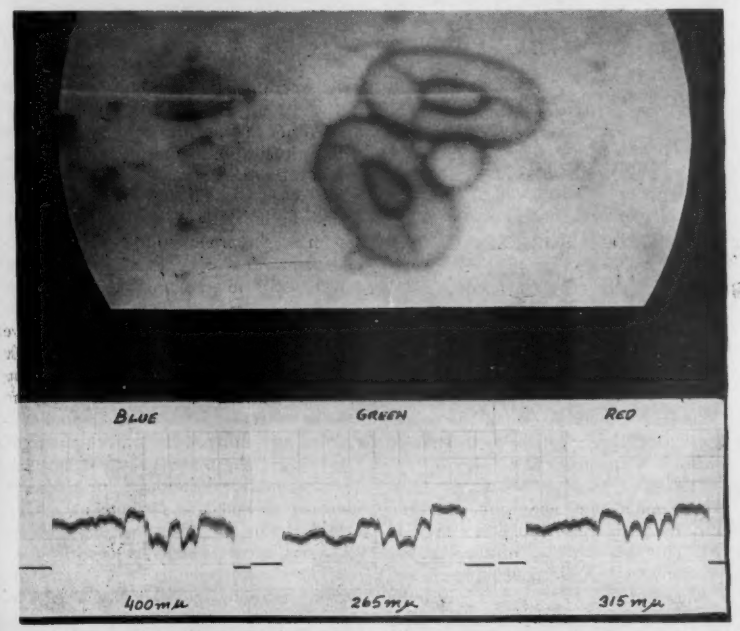

Fig. 11. Red cell of frog blood and oscillograms representing transmission at three ultraviolet wavelengths along selected scanning line.

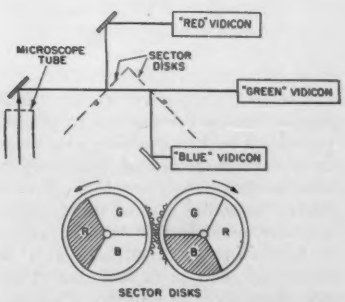

Fig. 12. Simultaneous color camera for television color-translating microscope.

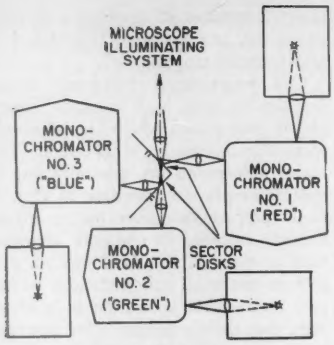

Fig. 13. Sector-disk illuminator for television color-translating microscope.

into color differences can make it a valuable tool in the rapid diagnosis of any disease whose onset is characterized by intracellular chemical changes. The detection of small quantities of a specific absorbing material can be further facilitated by modulating the gun cathode bias for the color channel correlated with the absorbed wavelength at a low frequency (of the order of 1 cycle per second), since the eye is very sensitive to the resulting flicker.

Modifications

An immediate improvement considered for the construction of the instrument is the replacement of the quartz lens in the illuminating system by quartz-fluorite achromats. This should eliminate the need for readjustment of the optical system of the illuminator with changes in wavelength selection and should lead to more nearly identical illumination at the three wavelengths.

A second change under consideration is the replacement of the single-image-orthicon camera by a three-Vidicon camera, as indicated schematically in Fig. 12. The beam of radiation from the microscope is directed successively to the "red," "green," and "blue" Vidicon—all of them, of course, of the experimental ultraviolet-sensitive type—by a pair of coupled sector disks synchronized with the vertical deflection; in Fig. 12, the shaded areas represent minor surfaces, while the clear areas transmit incident radiation unhindered. With such an arrangement, the camera becomes a simultaneous camera, and a standard simultaneous color monitor can be employed to view the picture. Vidicon lag no longer has an adverse effect on color purity (except in the viewing of objects in rapid motion), but merely serves to reduce flicker effects observed in the reproduced picture.

A similar system of sector disks (eventually rigidly coupled to those in the camera) may be employed in the illuminator to direct radiation from the three monochromators into the substage of the microscope (Fig. 13). This system possesses the advantage of rendering the timing of the pulsing of the light sources relatively uncritical and of achieving exact optical superposition of the three illuminating sources (*12*).

References and Notes

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10. If the three "separation negatives," corresponding to the three selected wavelengths, are preferred, they may be obtained either by photography of the monochrome monitor which is invariably employed for adjustment of the system or by using one color frame at a time.
11. P. K. Weimer and A. D. Cope, *RCA Rev.* 12, 314 (1951).

12. We are indebted to a number of workers at the Rockefeller Institute for Medical Research and at New York Hospital for supplying material for examination with the new instrument—in particular, to P. Weiss and A. C. Taylor for tissue cultures, M. A. Rudzinska for protozoans, E. L. Tatum for fungi, and G. N. Papanicolaou for cancer cells. The television equipment employed was made available on loan by RCA Laboratories. Carl Berkley made most of the preparations and contributed suggestions on the equipment. Other suggestions with respect to receiver modifications and the optical system were made by L. E. Flory and E. G. Ramberg of RCA Laboratories. The illuminating system was designed by P. Nolan of the Farrand Optical Company. The instrument represents an example of the effectiveness of cooperation between biologists and physical scientists in the development of new methods of biomedical investigation which could not have been achieved by either group working alone. It is now available at the Rockefeller Institute for Medical Research for cooperative investigations. Collaboration in the development of its uses and applications is welcomed.

The Maser

A Molecular Amplifier for Microwave Radiation

W. H. Culver

Electrical amplifiers in use today usually employ the motions of charged particles in electric or magnetic fields, as in vacuum tubes and transistors, or some nonlinear macroscopic property of matter, as in the case of the magnetic amplifier. An altogether different method of amplifying electrical signals is by stimulated emission of radiation. A device which uses this principle is called a maser (rhymes with razor). The word was coined by Townes and associates at Columbia University from the words *microwave amplification by stimulated emission of radiation* (*1*).

The maser principle was suggested by Weber in 1953 (*2*) and again independently by Bassov and Prokhorov in 1954 (*3*). The idea was used in a microwave spectrometer by Gordon, Zeiger, and Townes in 1954 (*4*). Within about the last year a large number of papers have been published on the subject, analyzing the theory and proposing new ways of incorporating the idea into practical devices (*5–17*).

Although the concept of this method of amplification is only a few years old, and although its successful embodiment into an instrument that can be used outside the laboratory awaits further development, its promise for future applications has aroused great interest in many technical fields. The main reason for this is that masers can operate with very low internal noise, much lower than the noise of the microwave amplifiers presently used. Thus, masers offer the possibility of greater ultimate sensitivities in the fields of radio astronomy, communications, and radar. Microwave spectrometers using the maser principle have already established their usefulness. Masers can be designed to oscillate at a very stable frequency, thus providing a basis for very accurate time standards.

The development of the maser was made possible by recent research in

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microwave spectroscopy. It is a very dramatic example of the unpredictable contributions made by basic research to many fields of technology.

Principle of Operation

The way in which a maser amplifies an electrical signal must be described in terms of the interaction of individual atoms and molecules with electromagnetic fields. Atoms and molecules can possess different amounts of internal energy which are determined by their electron configurations. They can exist for appreciable times only in a definite set of configurations called "stationary states," each of which is characterized by a definite internal energy. In general, an atom may not possess arbitrary amounts of internal energy, for only energies associated with the stationary states are allowed. In free atoms and molecules, and also sometimes in atoms in a solid, the allowed energies, called energy levels, are narrow, discrete levels separated by ranges of unallowed energies.

Under certain conditions an atom in one state may interact with its environment, losing or gaining the correct amount of energy to allow it to make a transition to another state. The amount of energy exchanged is just that required to make up the difference in internal energy of the atom in the initial and final states.

An atom can lose or gain energy by interaction with an electromagnetic wave or by interaction with other atoms. It may also change spontaneously to a state of lower energy by emitting a photon of electromagnetic radiation of energy ΔE and frequency $\nu = \Delta E/h$, where ΔE is the difference in energy between the initial and final states, and h is Planck's constant.

A very general thermodynamic argument due to Einstein proves that P_{AB}, the probability that radiation will induce an atom that is in state A to make a transition to state B, is equal to P_{BA}, the probability that the same radiation will induce an atom in state B to make a transition to state A. From quantum mechanics we find that such a transition is likely only when the frequency of the radiation is nearly equal to the difference in the energy of the two states divided by h—that is,

$$|E_A - E_b| = h\nu_{AB}$$

When electromagnetic radiation induces a transition in which the atom gains energy, this energy is taken from the electromagnetic wave. Likewise, when the radiation induces a transition in which the atom loses energy, this energy is added to the electromagnetic

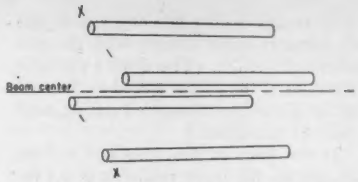

Fig. 1. Electrostatic focusing system for NH_3 molecules.

wave. This addition to the electromagnetic wave is in the form of one photon of frequency ν_{AB} that is coherent with the exciting wave (has the same phase, direction, and polarization).

When matter is in thermal equilibrium, the number of atoms in the ith state is proportional to

$$e^{-E_i/kT}$$

where E_i is the energy of the ith state, k is the Boltzmann constant, and T is the absolute temperature. Thus, the number in the state goes down exponentially with an increase in the energy of the state. If state B has greater energy than state A, the ratio of the number of atoms in the two states will be

$$N_B/N_A = e^{-\frac{h\nu_{AB}}{kT}}$$

If material in thermal equilibrium is irradiated with an electromagnetic wave of the proper frequency, the number of induced transitions that absorb energy from the wave is given by $N_A P_{AB}$, while the number of induced transitions that take energy from the atoms and give it to the wave is

$$N_B P_{BA} = N_B P_{AB} = N_A P_{AB} e^{-\frac{h\nu_{AB}}{kT}}$$

Thus, if the atoms are in thermal equilibrium at any temperature T, there are more atoms in the lower state than in the upper state, and therefore there are more transitions from the lower state to the upper than there are in the reverse direction. This means a net absorption of energy from the radiation by the material. However, if by some means the thermal equilibrium can be destroyed in such a manner that there are more atoms in state B than in state A, there will be a net loss of energy by the atoms and an amplification of the power in the electromagnetic wave. This is the principle of operation of the maser amplifier.

In order to make a maser that will amplify an electromagnetic wave of a given frequency, it is necessary to find an atom or molecule with energy levels separated by the proper energy and between which the probability of induced transition, P_{AB}, is sufficiently large. Then it is necessary to use some trick to get more atoms in the upper state than in the lower state. Finally it is necessary to provide a method by which the electromagnetic energy can interact with the material. Because of the very low noise level possible in this type of amplifier, it would be desirable to build it to operate at all frequencies from low-frequency electrical signals up to optical frequencies. However, it appears that the necessary requirements for maser operation can be met only in the microwave region of the spectrum. This is due in part to the need for resonant cavities to increase the interaction of the material with the radiation. A number of ingenious masers have been built or proposed. We will investigate the problems of making masers by discussing some of them.

Molecular Beam Maser

The original maser built at Columbia University by Gordon, Zeiger, and Townes used ammonia gas as the working substance. The two energy levels of the ammonia molecule used were the "ground" level, the lowest energy level of the molecule, and an energy level lying slightly above it. The energy separation of these levels is such that transitions between them are caused by microwave radiation with a frequency of 24,000 megacycles per second or a wavelength of 1.25 centimeters.

The method used to obtain an excess of ammonia molecules in the upper state was to separate physically the molecules of the two states and discard the molecules that were in the lower state. This was accomplished by making use of the Stark effect, the change in energy of these two states when they are placed in an electric field. When an ammonia molecule is placed in an electric field, the energy of the lower state is lowered and the energy of the upper state is raised. Thus there will be a force on a molecule in the lower state that is in the direction of the gradient of the electric field strength, while there will be a force that is in the direction opposite to the gradient of the electric field strength on a molecule that is in the upper state.

The ammonia molecules issue from a source into an evacuated chamber in a well-collimated beam. This beam is directed down the axis of an electrostatic focusing system made of four or more electrical conductors that are made alternately positive and negative as shown in Fig. 1. In such a configuration the gradient of the electric field strength is away from the center of the beam. Thus molecules in the upper state are pulled in toward the beam axis while those in the lower state are expelled outward from the beam, and physical separation of the molecules in the two states is accom-

plished. Molecules in the upper state are allowed to flow into a microwave cavity that is resonant at 24,000 megacycles per second.

If microwave energy of this same frequency is fed into the cavity, it will induce transitions of the ammonia molecules from the upper state to the lower state, releasing photons of microwave energy. Although the radiation can also induce transitions in the reverse direction and thereby absorb microwave energy, there are so few molecules present in the lower state that this seldom occurs. Thus, on the average, energy from the molecules is added to the energy of the electromagnetic wave. If this gain in energy is greater than the electrical losses in the cavity, more microwave energy can be taken from the cavity than is supplied to it. Thus the microwave signal has been amplified.

The gain of such an amplifier is proportional to the probability that the input radiation will stimulate the emission of a photon of radiation. This probability is of course proportional to the excess number of molecules in the upper energy level over the number in the lower energy level. It increases as the Q of the cavity increases because the higher electromagnetic energy density in a cavity of higher Q interacts more strongly with the ammonia molecules. (The Q of a cavity is the ratio of the energy stored in the cavity to the energy dissipated during each cycle of oscillation.)

If the gain of the amplifier is high enough so that input radiation is not required to make up for electrical losses in the cavity, the maser will act as a microwave oscillator. It will give a microwave output even without a microwave input. Since the frequency of oscillation is determined primarily by the spacing of the energy levels of the ammonia molecule, there is very little frequency drift due to macroscopic changes in the maser. The frequency of such an oscillator has been observed to have a random drift of only one part in 10^{13} in a period of two hours (*17*). (The limit of stability of a temperature-stabilized quartz oscillator is about one part in 10^9.)

The power output of the ammonia maser amplifier is low—of the order of 10^{-10} watt. Because of the sharpness of the ammonia energy levels, these amplifiers also have a very narrow bandwidth —of the order of a few kilocycles per second or less. The only advantage they have over conventional amplifiers is that they have much lower internal noise and can therefore amplify much weaker signals.

Noise in masers comes from several sources. Two sources of noise that can be illustrated with ammonia masers are given below. If the walls of the cavity can absorb microwave radiation, then, from general equilibrium considerations (Kirchoff's Law), they will also emit similar radiation. The rate of emission can be calculated from the black-body formula if the temperature and emissivity of the walls are known. If the emissivity is low the emission from the walls will be much less than it is from a black body at the same temperature. This radiation contributes to the background against which a signal must stand out.

Another source of noise in masers is spontaneous emission of microwave photons by molecules in the upper state. The probability of a free atom or molecule radiating spontaneously is proportional to the cube of the frequency of the radiation. Although a free atom may emit an optical photon spontaneously in 10^{-8} second, the spontaneous radiation of a microwave photon in a molecular beam maser is usually very improbable compared with the probability of stimulated emission by the input signal. This is not necessarily true for some types of masers considered below in which cooperative effects of many atoms may increase the probability of spontaneous emission (*18*).

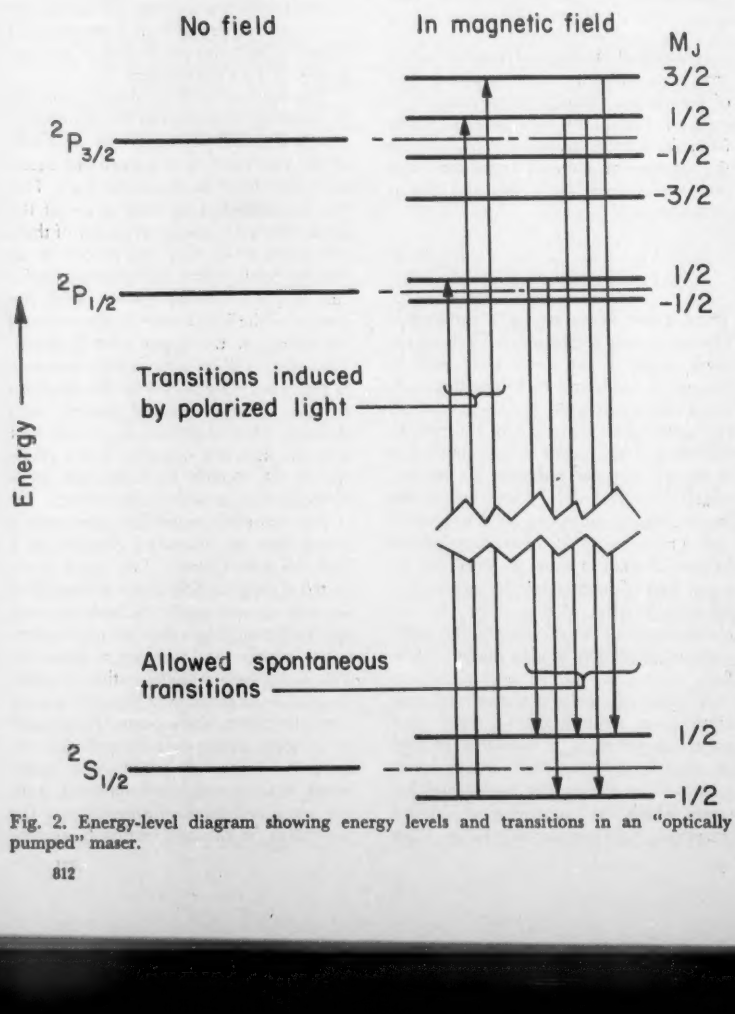

Fig. 2. Energy-level diagram showing energy levels and transitions in an "optically pumped" maser.

"Negative-Temperature Maser"

A second type of maser uses a method to obtain an increase in population in the upper state similar to that used by Purcell and Pound in obtaining "negative temperatures" (*19*). In this method the atoms used are placed in a magnetic field B, where the ground state will split up into a number of magnetic sublevels of different energy. The energy of the ith sublevel with respect to its zero field value is given by

$$E_i = \mu_0 g M_{Ji} B$$

where μ_0 is the Bohr magneton (this is a constant equal to 9.27×10^{-21} erg/gauss), g is the Lande g factor, and M_{Ji} is the component of the total angular momentum of an atom in ith state in the direction of the magnetic field in units of $h/2\pi$. When thermal equilibrium is established, the number of atoms in each level becomes proportional to $e^{-E_i/kT}$. Now if the direction of the magnetic field is suddenly reversed, the value of M_{Ji} for each state is suddenly multiplied by -1. A state that previously had energy E_i now has energy $-E_i$. Thus the population of each of these states is proportional to $e^{+E_i/kT}$, the distribution they would have according to the Boltz-

mann formula for a temperature of $-T$; hence the term *negative temperature*. Thus we have the condition for maser operation—namely, a greater number of atoms in the upper states than in the lower states.

The negative-temperature maser has the advantage over the ammonia maser that, when it is used as an amplifier, it can be tuned to a different frequency range. Varying the magnitude of the magnetic field varies the energy-separation of the energy levels, and hence, the frequency of operation. Inhomogeneities in the magnetic field and in the natural breadth of the energy levels of many of the substances which might be used would also increase the bandwidth over that of the ammonia maser.

This type of maser has two main disadvantages. Since its gain decreases exponentially as the atoms approach thermal equilibrium, it is necessary to recharge the energy source periodically. Thus the operation of the maser will be intermittent. In addition, a very low temperature is required in order to obtain a large population difference between the states. For this type of maser the noise due to spontaneous emission may be relatively important (*18*).

"Optically Pumped" Maser

A third class of masers uses the method of optical pumping (*20, 21*) to excite the atoms of the working material into an upper energy level. A simplified example of the optical-pumping process as applied to sodium is illustrated in the energy-level diagram in Fig. 2. The energy levels produced by the interaction of the nucleus with the electronic structure of the atom are neglected here, for they only complicate the problem without changing its basic character.

The familiar yellow lines in the spectrum of the sodium atom are produced by transitions from $^2P_{3/2}$ and $^2P_{1/2}$ states to the ground $^2S_{1/2}$ state. When a sodium atom is placed in a magnetic field, each of these levels splits up into sublevels as shown in the diagram. The frequency that causes a transition between the $M_J = 1/2$ and $M_J = -1/2$ sublevels into which the ground state splits is 5.6 megacycles per gauss of the applied magnetic field. The optical-pumping process is used to obtain an excess population in the upper of these two levels, and thus it permits a maser to operate between them.

If circularly polarized light from a sodium lamp is directed into the sodium vapor in the maser along the direction of the applied magnetic field, the light is absorbed by the sodium atoms in the ground levels and excites them into one or the other of the ^2P levels. Because of the circular polarization of the light, only transitions in which M_J changes by $+1$ are allowed (see Fig. 2). These excited atoms spontaneously emit a light photon and drop down to one of the ^2S levels. The allowed spontaneous transitions are those for which M_J changes by ± 1 or 0, as indicated in the diagram. It can be seen by following through the allowed transitions that atoms in the lowest ^2S level may be "pumped" into the upper ^2S level, but once an atom is in the upper level it cannot get back to the lower level by this process. In this way the number of atoms in the upper level can be increased over the number in the lower level.

Attempts to make a maser of this type have thus far been unsuccessful because the excess number of atoms in the upper state could not be made large enough. A slightly altered technique being applied by Wolfgang Franzen at Arthur D. Little, Inc., promises to be more successful.

Solid-State Maser

The most successful maser amplifiers developed so far have been solid-state, three-level masers. The method of operation was first proposed by Bassov and Prokhorov (*5*) and was developed in greater detail by Bloembergen (*7*).

The use of a solid in a maser has the advantage of providing a much greater density of participating atoms. The operation is made more complicated and in some instances is hampered by the interactions of the participating atoms with the lattice of the crystal.

Although most solid materials have broad energy bands rather than sharp levels, there are some atoms, notably those of the transition and rare-earth elements, that possess levels that are narrow enough to be used in masers. The position of these levels is influenced by the environment of the atom in the crystal. These levels may be split into a larger number of levels, and their position may be altered by application of a magnetic field.

The method proposed by Bassov and Prokhorov and by Bloembergen for obtaining more atoms in the upper of two energy levels is as follows. Consider three unevenly spaced energy levels of an atom in a crystal as shown in Fig. 3. If the energy levels are in thermal equilibrium, the number of atoms in levels B and C will be

$$e^{-\frac{h\nu_{AB}}{kT}}$$

and

$$e^{-\frac{h\nu_{AC}}{kT}}$$

times the number in level A. If the material is then exposed to intense radiation of frequency ν_{AC} a new equilibrium will be established in which there are the same number of atoms in the two levels A and C. The number of atoms in level B can be either less than or greater than the number in levels A and C, depending upon the relative transition probabilities between the three levels. These transition probabilities are determined by the interaction of the atoms with the crystal lattice and are very much greater than the spontaneous transition probabilities of a free atom. We will use the notation W_{ij} to denote the probability that a lattice-induced transition from state i to state j will occur.

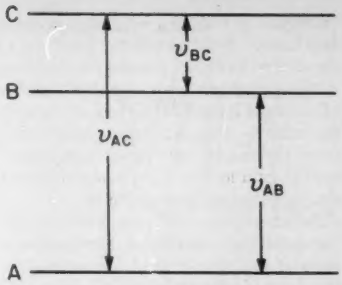

Fig. 3. Energy-level diagram showing energy levels and transitions in a solid-state maser.

If $W_{CB} \gg W_{BA}$, the population of level B will be in thermal equilibrium with the population of state C above it. Thus there will be more atoms in state B than in state A, and it will be possible to operate a maser at frequency ν_{AB}. Likewise, if $W_{BA} \gg W_{CB}$, it will be possible to operate a maser at frequency ν_{BC}.

Solid-state masers are operated at liquid helium temperatures (4°K and below) for several reasons. First it should be noted that the maximum population difference $N_B - N_A$, and hence the maximum gain, is achieved when the ratio N_B/N_A is as large as possible. The maximum value this ratio can have is

$$e^{\frac{h\nu_{BC}}{kT}}$$

This is possible when state B is in thermal equilibrium with state C. Thus it is desirable that the ratio ν_{BC}/T should be large. Unfortunately ν_{BC} must be less than the frequency ν_{AC} at which power to operate the maser is delivered. Since $k/h = 2.1 \times 10^{10}$, the ratio N_B/N_C is only e when ν_{BC} is 20,000 megacycles per second and the temperature is 1 degree Kelvin. Because sufficiently powerful sources of microwave energy are not available at frequencies above 30,000 megacycles per second, it is necessary to operate this type of maser at a very low temperature in order to realize its maximum gain.

Although the gain of a maser is pro-

portional to only $N_B - N_A$ and is not a function of the total number of atoms of the active material present, fluctuations in the gain result when the total number of atoms is large (*22*). Thus, if we wish to achieve the ultimate performance from the maser, we cannot compensate for the gain lost by using a warm crystal simply by using more material.

Another important reason for operating solid-state masers at low temperatures is that the desired low values for the lattice-induced transition probabilities have been achieved only at low temperatures. If these transition probabilities are increased, more power is required to maintain the equilibrium of population densities that permit maser operation. If these transition probabilities are high, they also contribute to the noise level of the amplifier.

In spite of all the difficulties associated with the design and operation of a solid-state maser, successful amplifiers of this type have been constructed at Bell Telephone Laboratories by Scovil, Feher, and Seidel (*13*) and by J. W. Meyers at the Lincoln Laboratory of Massachusetts Institute of Technology. The Bell Laboratory maser, which uses a gadolinium atom in a crystal of gadolinium ethyl sulfate, operates at about 9000 megacycles per second. The more recent solid-state maser operating at the Lincoln Laboratory uses chromium atoms in a potassium chrom cyanide crystal and operates at 2800 megacycles per second. It amplifies linearly up to an output of 10^{-6} watt with a maximum output of 10^{-5} watt. The amplifier has gains of 40 decibels and 10 decibels with bandwidths of 25 and 500 kilocycles per second, respectively. The noise temperature of the amplifier has been estimated conservatively to be under 100°K.

We can expect considerable progress in the field of solid-state masers. Research into the properties of solids will reveal new materials with more suitable properties. A better understanding of the effects of different lattice structures and of magnetic fields upon the position of energy levels and upon transition probabilities is needed. If more is known about the characteristics of very high energy states in crystals, perhaps some form of optical pumping can be used in a solid-state maser, thus removing some of the reasons for the present unfortunate requirement that it be operated at a very low temperature. This is a field where clever invention has played as important a part as basic research. Certainly no one can predict what part new inventions will play in the future.

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Finding Chemical Records by Digital Computers

Louis C. Ray and Russell A. Kirsch

The National Bureau of Standards and the United States Patent Office are actively collaborating in a long-range program to develop and apply automatic techniques of information storage and retrieval to problems of patent search. An important preliminary phase of this program has been the carrying out of experiments with methods for locating information in large files of technological and scientific information.

In the granting of United States patents, it is necessary for patent examiners to refer to collections that may, in principle, contain from 10^6 to 10^7 documents. When an examiner conducts a literature search to determine whether a patent application represents a novel idea, which then must be tested against established criteria for patentability, he must search insofar as possible through all literature in the public domain that might possibly contain any information pertinent to the given application. It has been estimated that 60 percent of the time spent by an examiner in processing a patent application is devoted to searching the technical literature. In an attempt to reduce this expenditure of time, the National Bureau of Standards–Patent Office group has considered, among other techniques, the use of automatic data-processing systems.

By an automatic data-processing system (ADPS) is meant a collection of machines, usually but not necessarily electronic in nature, which have the ability to process information in accordance with internally stored programs and which can perform a whole data-processing task involving the use of data-storage facilities of diverse natures without the necessity for manual intervention. The system also includes devices for the preparation of input data and the reproduction of output data. SEAC, the NBS *E*lectronic *A*utomatic *C*omputer, is an automatic data-processing system; it has been used in successful preliminary experiments wherein a collection of over 200 descriptions of steroid compounds is exhaustively searched to answer typical questions that may occur in evaluating patent applications for new chemical compounds. This article (*1*) describes some theoretical ideas on the use of automatic data-processing systems for literature searching; these ideas have resulted from experiments in searching through chemical information.

In considering any attempt to automatize the searching of technical literature in the U.S. Patent Office, it must be remembered that the historical nonautomatic or manual method of searching which is presently in effect at the Patent Office utilizes the best intellectual efforts

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of some 8000 examiners highly trained in diverse technologies and in the legal aspects of isolating significant information from large technical files. Consequently, there is no a priori reason to believe that there is any single over-all solution to the literature-search problem in the Patent Office which will function as effectively as this trained corps of examiners. With this consideration in mind, one area of the inventive arts was selected for initial experimental investigation in the hope that empirical solutions in that area could be put into productive operation. A bonus from the solutions has been the development of theoretical and experimental techniques which should prove applicable to the searching of technical literature in other areas with which the Patent Office is concerned.

The area selected for initial experimental investigation was that of "Composition of Matter"—that is, patents generally concerned with what may loosely be classified as chemistry. This area was recommended for initial investigation by the Advisory Committee on the Application of Machines to Patent Office Operations (*2*). Chemists have for a long time been concerned with information retrieval, and it was hoped that use could be made of some of the techniques that the chemists have developed. As it turned out, the experimental results obtained took advantage of a technique of chemistry that, historically, was probably not developed for the purpose of information retrieval—namely, the use of chemical structural diagrams for describing the chemical nature of matter.

It is of paramount importance to realize that in using automatic techniques for the retrieval of technical information, no more information can be obtained from a file than that information which is represented in the file according to a well-defined notational scheme. Because the method of representing chemical structures in diagrammatic form has just such properties, it was decided to experiment with the use of SEAC for searching through files of chemical structure diagrams in response to search requests fed into the machine.

Fig. 1. Fragment structure.

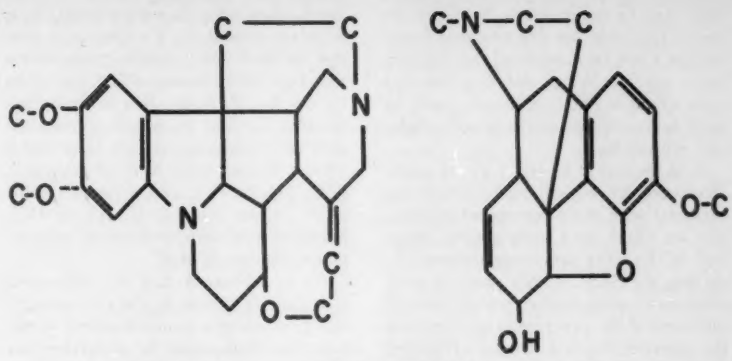

Fig. 2. (Left) Structure of brucine. (Right) Structure of codeine.

Searching Chemical Structures

Structure search problem. In the Patent Office, the examiners in the chemical arts have frequent need for performing generic searches through structure diagrams. As an example, it can be seen that the fragment structure which is given in Fig. 1 is contained in the two compounds brucine and codeine shown in Fig. 2. Unmarked vertices in the structures are understood to represent carbon atoms (C). Notice that the six-member ring with the nitrogen (N) occurs in codeine even though the diagram of codeine indicates the ring in a distorted manner. We can say that the two compounds shown in Fig. 2 share the generic property of containing this fragment. Some of the experiments performed on SEAC were concerned with developing a method for performing generic searches of this type through a file of structures taken from the art of steroid chemistry.

Structure search routine. The Patent Office search requires an unambiguous coding system in which any combination of atoms and bonds can be represented for purposes of retrieval. The traditional coding system (*3*) is not suitable for mechanized search because a given compound can be represented in conceptually different ways and because the system is so complex that it can be used only by a trained chemist. Opler (*4*) of the Dow Chemical Company has developed a code for use in machine searching. This code is flexible, but it is not suitable for Patent Office searches because it does not represent the most fundamental units of the chemical structure, the atoms and their bonds which are directly required in many typical patent searches. An example of a code suitable for machine searching was described by Mooers in the "Zatopleg" (*5*) system of ciphering structural formulas. Mooers' method of representing compounds provided the basis for representing the input data in the SEAC structure search routine described below. Methods for actually searching such data had to be developed.

In the system used on SEAC, each atom in a structural diagram is numbered serially in arbitrary order. One unit of computer storage, called a word, is given to each atom to represent its position in the structure. In each word are listed the numbers of the other atoms, up to four, that are attached to the atom represented by the word. The element symbol and the serial number of the atom are also placed in the word. Thus each atom word has six fields; the serial number of the atom, four connections fields, and an element symbol.

As an illustration, consider the compound, chloral, shown in Fig. 3. The coding would proceed as follows:

First, the atoms and all bonds other than single bonds are numbered in any arbitrary order as shown in Fig. 4. Then, a list of the connections to each component of the structure is made, as shown in Table 1. Finally, the element symbol of the atom the word represents is put in each word, as shown in Table 2.

The list (Table 2) represents the complete code for the structure. The struc-

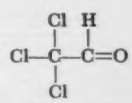

Fig. 3. Structure of chloral.

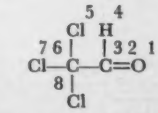

Fig. 4. Structure with atoms and double bond numbered.

ture may be easily drawn by using the code. The code for any structure is not unique since, by numbering the atoms in some other arbitrary order, a different code would be obtained. It may easily be seen, however, that all the possible codes are equivalent.

It is desired to search a file of coded structures for all structures which are identical with some compound in question or which have some generic property in the sense previously defined. To do this, the SEAC search program tried to make an atom-to-atom match between the atoms of the structure in question and the atoms of the first structure recorded in the file. Each match that is made is considered as tentative by the program until the search through the first file structure is completed. Whenever failure to match is discovered by the program, the program tries to go back to the previous match to make a new match. If the program finds that all possible first matches lead to irreconcilable mismatches, it will reject the first file structure and proceed on to the next. When a one-to-one correspondence exists between each of the atoms of the question and the atoms of part of the file structure that is being examined, the routine accepts the structure by printing on the computer output an indication of which structure was found. The search routine continues this process until the whole file has been searched.

The details of the search routine are given in the flow chart in Fig. 5. The symbols used in the chart are defined as follows: I, II, III, and IV denote the four connection fields in each atom word; Q_i is a question atom word; F_b is a file atom word; N_i is a temporary storage location for question atom words matched with corresponding file atom words (R); R_i R_j is a temporary storage location for file atom words matched with corresponding question atom words (N); α denotes fields of R (it can equal I, II, III, or IV), and β denotes fields of N (it can equal I, II, III, or IV). Standard flow-chart terminology in computer program is used.

Use of Screens. As fast as a high-speed electronic computer is, the fact remains that performing a detailed search of the type described would be altogether too time-consuming unless some short-cuts could be devised which would in no way compromise the exhaustiveness or accuracy of the search, while speeding up the process greatly. A technique is needed that will enable the automatic data-processing system to perform what is for the machine a cursory inspection of small pieces of data in such a manner that most structures that will not satisfy the search requirement will be rejected immediately. Such a technique is called a "screen" or a "screening device." It is essential that a screening device should never cause a structure to be rejected which does, in fact, meet the search requirement. It is acceptable, however, if the screen allows some structures to be considered further by the structure search routine even though they are subsequently rejected as failing to meet the search requirement.

By now, it will have become obvious to any chemist that one such useful screen is inherent in the empirical formula of a chemical structure. In other words, by storing in the file, along with a description of the chemical structure, a list of the number of occurrences of each atom in the structure, it is possible to find out whether there are enough atoms of the right type present to satisfy the search requirement. This screen was incorporated into the SEAC search program and on most searches it enabled the computer to reject quickly the vast majority of structures that would otherwise have been rejected only after a long computational procedure.

Other screens that were considered but not experimented with would make use of topological properties of the chemical structures. One such simple screen specifies the number of rings within the structure. Obviously, if one were searching for some generic structure having, say, three benzene rings, a structure having even 500 atoms in it could not contain the one being searched for unless there were at least three rings somewhere within the 500-atom structure.

Other topological properties that could serve as screens would be the longest non-self-intersecting path that could be traced through the structure, and a count of the number of atoms with each of the possible valences. However, these topological properties were not investigated experimentally.

The important properties to be sought for in devising screens for any type of searching, chemical or otherwise, are that the screens must be substantially independent of one another and that they must have universal applicability to all documents in a collection. These prop-

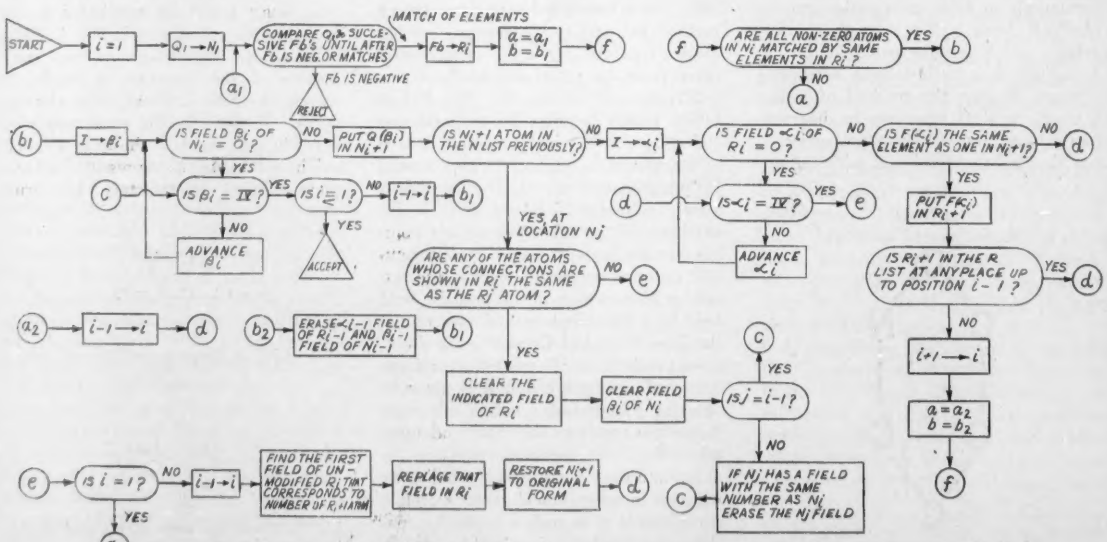
START
i = 1
Q1 → N1
COMPARE Q1 & SUCCESSIVE Fb's UNTIL AFTER Fb IS NEG. OR MATCHES
MATCH OF ELEMENTS
Fb IS NEGATIVE
REJECT
Fb → R1
a = a1
b = b1
ARE ALL NON-ZERO ATOMS IN Ni MATCHED BY SAME ELEMENTS IN Ri ?
YES
NO
I → βi
IS FIELD βi OF Ni = 0 ?
PUT Q(βi) IN Ni+1
IS Ni+1 ATOM IN THE N LIST PREVIOUSLY?
I → αi
IS FIELD αi OF Ri = 0 ?
IS F(αi) THE SAME ELEMENT AS ONE IN Ni+1?
IS βi = IV ?
IS i ≧ 1 ?
i-1 → i
ADVANCE βi
ACCEPT
YES, AT LOCATION Nj
IS αi = IV ?
ADVANCE αi
PUT F(αi) IN Ri+1
ARE ANY OF THE ATOMS WHOSE CONNECTIONS ARE SHOWN IN Ri THE SAME AS THE Rj ATOM ?
IS Ri+1 IN THE R LIST AT ANY PLACE UP TO POSITION i - 1 ?
i-1 → i
ERASE αi-1 FIELD OF Ri-1 AND βi-1 FIELD OF Ni-1
CLEAR THE INDICATED FIELD OF Ri
CLEAR FIELD βi OF Ni
IS j = i-1 ?
i+1 → i
a = a2
b = b2
IS i = 1 ?
FIND THE FIRST FIELD OF UNMODIFIED Ri THAT CORRESPONDS TO NUMBER OF Ri HATOM
REPLACE THAT FIELD IN Ri
RESTORE Ni+1 TO ORIGINAL FORM
IF Nj HAS A FIELD WITH THE SAME NUMBER AS Ni ERASE THE Nj FIELD

Fig. 5. Flow chart of the chemical-structure search routine.

erties are never completely achieved in practice, but they can be approached when the search is limited to narrowly defined subject matter.

Grouping of Information. In deciding upon a method for representation of structure diagrams for search by the automatic data-processing system, it was necessary to decide what data about a structure diagram would be represented in the code as it was stored in the machine file. Certainly an atom-by-atom description would give a completely general and flexible method for representing chemical information. But a difficulty arose in certain of the chemical arts where the distinction between one chemical and the next is very slight in the atom-by-atom description. On the other hand, very useful discrimination among the members of such a class could be made by including in the description certain characteristics that were peculiar to that particular class. The problem here is one that is undoubtedly a characteristic of systems for coding information wherever the information assumes diverse forms—namely, how much generality shall be sacrificed in order to provide a high degree of discrimination in certain isolated areas of the collection where most of the documents contain similar information.

A solution to the problem that is practical if ADPS searching is to be used, but which is probably not practical for use with simpler systems (for example, punched cards) is to have special coding systems applicable for certain documents in a collection. These coding systems serve as adjuncts to one (or more) coding system which describes the entire collection. If, in searching through a collection, the screening devices fail to reject a document for which a special coding system is applicable, then special instructions are automatically made available to the automatic data-processing system to enable it to search the codes for a special document in terms of the special coding system being used. It is quite practicable, when searching with an automatic data-processing system, to have documents scattered through a collection that have been described with special coding systems not generally used for the whole collection. This technique becomes costly of machine searching time only when the number of such special documents is so large that it becomes necessary for the machine system frequently to call up its auxiliary instructions to handle the special coding situation.

With these considerations in mind, some special coding methods suggested by the Patent Office were used for coding structures in the steroid chemical art. These coding rules permitted fine distinctions to be made between various compounds in the steroid art, even though the coding rules depended upon certain chemical structure properties which were quite peculiar to the steroid art and, therefore, inapplicable for searching other types of chemical structures.

Table 1. List of connections to each component of the structure shown in Fig. 4.

Component No.	Connections
1	2
2	1, 3
3	2, 4, 6
4	3
5	6
6	3, 7, 8, 5
7	6
8	6

Table 2. Complete code for the structure shown in Fig. 4.

Component No.	Connections	Element symbol
1	2	O
2	1, 3	=
3	2, 4, 6	C
4	3	H
5	6	Cl
6	3, 7, 8, 5	C
7	6	Cl
8	6	Cl

Use as an Information-Retrieval System for Other Purposes

The experiments and theoretical considerations thus far described have been concerned with the use of the automatic data-processing system as a tool for actually performing a search through a file of information (in this case, chemical in nature). However, the use of automatic data-processing systems in retrieval of information extends considerably beyond the activity of actual searching. This section describes the use of such machine systems for processing data as part of an over-all information-retrieval system.

Checking data. It is evident that the file of information through which a search will be performed must be prepared without error, for any error in a recorded piece of information represents the loss of some information from the file. In the experiments with retrieval of chemical structures, the original file was prepared by the Patent Office in the form of about 2500 punched cards that described about 250 chemical structures. Since one of the features of the coding scheme used was its lack of reliance upon chemical knowledge for encoding structures, a group of punched-card typists were given the set of 250 pictures describing the structures to be encoded. The operators read the pictures and punched the descriptions on cards without the intervention of any supervision from a chemist. As was to be expected, there were some cards out of the 2500 that contained errors, and the problem was to find the errors and correct them.

Since the data were ultimately to be used as input to SEAC, they were first transcribed from punched cards onto magnetic wire (which was the principal SEAC input-output medium at the time of the tests described). Then a program was written for SEAC to take these data from the wire and check them. It is important to note that this data-checking program was entirely unrelated to the subsequent SEAC search program. The data were checked for internal consistency and for their adherence to the coding rules that had been established. The result was that about 50 punched-card errors were caught and that a copy of those parts of the file containing no errors was produced. This expurgated file could then have been used by another machine. If the coding system had been of suitable nature, other simpler mechanisms could have done the searching through data that had been checked by the automatic data-processing system.

Here, then, is an example of the use of an automatic data-processing system as part of an information-retrieval system although the machine system need not serve as the searching device. In preparing a large file for occasional use, where the cost of a large machine system would not justify its use as a searching tool, the machine system might still profitably serve the function of checking the initial data to be entered into the system.

Transliteration. Another function that an automatic data-processing system can serve as part of an information retrieval system is that of transliterating data to be entered into the system from the forms that are most convenient for manual preparation of the data into forms more suitable for searching by machine. In the structure search experiment, the data to be used by SEAC had to be arranged in a certain format for most efficient utilization of the SEAC memory space. This format was sufficiently complicated that the punched-card operators could not be expected to prepare the data in that format with any reasonable speed or accuracy. Consequently, a program was written for SEAC which accepted data in a format convenient for the punched card operators and transliterated the data into the form desirable for SEAC searching.

Again we have an example of the use of an automatic data-processing system, not for searching, but in this case for transliterating data from one form into another. It should be noted that both the

input data for this transliteration program and the output produced by the machine followed completely rigorous rules of organization and arrangement. The automatic data-processing system was converting data from one well-defined coded form into another. The fact that this can be done readily with an automatic data-processing system should not lead one to the conclusion that data expressed in some natural language (for example, English) can be *translated* by machine into a coded form suitable for machine search. The problem of *machine translation* is a formidable one to which much effort is being devoted (*6*) both in the United States and elsewhere. What is claimed here is that the comparatively simple problem of *transliterating* from one code into another can be conveniently handled by an automatic data-processing system.

Another example of transliteration by SEAC which is the subject of some current experiments is its use for generating chemical structure descriptors for use by a simpler searching machine. It has been suggested by Mooers (*7*) that, for purposes of retrieval, complex structures such as chemical diagrams can be represented in terms of a list of, say, all the triples of atoms and bonds occurring within the structure. Thus, chloral (Fig. 3) would be described as consisting of combinations of the triples in the following list: Cl—C; C—C; —C—; —C=; C—H; C=O.

A simple search mechanism performing simple comparisons between similar types of triples in the search request and the file could retrieve complex structures without the necessity of doing the complex processing of data of the type performed by the structure search routine described earlier. It is not within the scope of this article to discuss the merits of such a search system. However, this example is mentioned to demonstrate that an automatic data-processing system can generate the *N*-tuple descriptors from a complete representation of the structure. If a large file of chemical structures is to be searched by a very simple mechanism using Mooers' *N*-tuple descriptors, the original file may be prepared in, for example, the form required for the SEAC structure search routine. It is then a fairly straightforward job to program SEAC to generate the *N*-tuple descriptors and consequently to produce as output a transliterated file all prepared for searching by more simple mechanisms.

Some present SEAC experiments are devoted to generation of the *N*-tuple descriptors from the file of steroid compounds previously described. It is intended, then, to run comparative tests on a file of chemical structures coded according to the two coding schemes. Any results obtained from such a comparison will be less significant, however, than the fact that such an experiment demonstrates the feasibility of simulating on a large automatic data-processing system the searching procedure of a simpler mechanism for purposes of comparative evaluation.

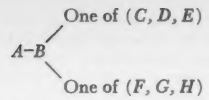

Fig. 6. Structure with alternatives.

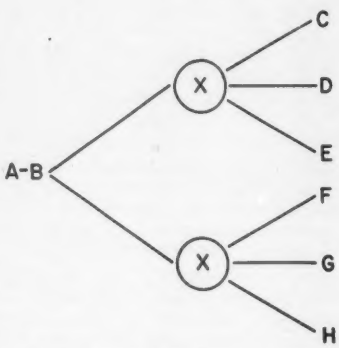

Fig. 7. Intermediate dummy element.

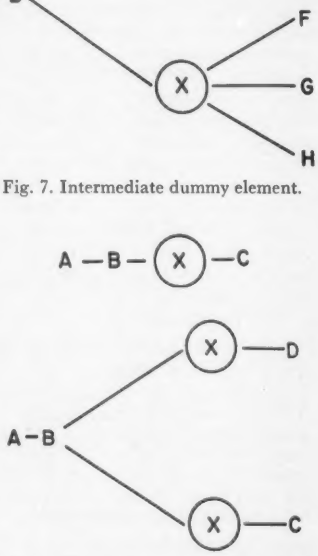

Fig. 8. (Top) Structure included in Fig. 7. (Bottom) Structure not included in Fig. 7.

Exploration of complex logical situations. In retrieval of information from Patent Office files, it often occurs that complex logical conditions must be imposed upon either the question or the file. A simple example of the way in which an automatic data-processing system can handle complex interrelationships occurs in the search for alternative patent disclosures.

It is quite common for an inventor to describe his invention in the following form: *A* plus *B* plus any one of the following three, *C*, *D*, or *E*, plus any one of the following three, *F*, *G*, or *H*. The elements *C*, *D*, and *E* are alternatives for each other, as are the elements *F*, *G*, and *H*, and any one of the first group may possibly be combined with any one of the second group for purposes of anticipating a subsequent patent claim. However, if someone were to claim the combination $A+B+C+D$, the patent described would not be relevant since *C* and *D* are disclosed only as alternatives for each other. It is desirable to be able to use a search machine that will not accept a patent like the first one described when searching for the latter.

One solution to this problem that has been proposed but does not appear to be practical is to code the alternative type of disclosure separately as each of the several types being described. Thus $A+B+$ one of (C, D, E) + one of (F, G, H) would be represented by $3 \times 3 = 9$ separate entries. In many real situations a number in the thousands would describe the number of possible combinations claimed in a chemical patent.

Another method for handling this type of situation on SEAC was suggested by the Patent Office; this method made use of the structure search routine. By the introduction of certain dummy elements into the chemical structure, several alternative structures could be coded in one large pseudo-structure. If the alternative structure of Fig. 6 is to be coded, it can be represented as shown in Fig. 7, where X (inside the circle) represents a dummy element. It can be seen that Fig. 8*a* is contained in the pseudo-structure of Fig. 7, but that Fig. 8*b* is not.

The handling of this complex type of alternative search is possible on an automatic data-processing system but difficult on a simpler mechanism. In a large information-retrieval system it may be possible to use simpler mechanisms than an automatic data-processing system for searching until a complex logical situation such as the alternative search arises, in which case the file may be made available to the automatic data-processing system for more complete searching.

There are other complex logical situations that arise in Patent Office searching for which it is not yet possible to announce experimental solutions. One particularly difficult one occurs when there is a reference that is complete except for a minor substitution of some component *A* for the desired component *B* and when, in an entirely separate patent, there is a statement attesting to the equivalence of *A* and *B* for the function concerned. It is often desirable to retrieve such a partly incomplete reference in conjunction with the reference stating equivalence. To date, however, no general solution to this problem is known.

Conclusions

The problems in information retrieval mentioned here have certainly been known to serious workers in the field for some time. Only recently, however, have

automatic data processing systems become sufficiently available to be considered as possible tools in an information-retrieval system. Thus the SEAC experiments indicate the practicality of using automatic data-processing systems for scanning a file of information at high rates. However, many mechanisms considerably simpler than an automatic data-processing system can also do such scanning, and the question remains open about the comparative advantages of an automatic data-processing system and simpler mechanisms for the actual process of looking at a properly organized file. In some retrieval situations, most notably in the Patent Office, the problem is of sufficient magnitude and complexity that the power of an automatic data-processing system to do more than just scan a file appears at first inspection to be a requirement. Where the machine system seems to offer a unique contribution is in the off-line jobs. For such functions as preparing a search prescription, editing a file, eliminating errors, transliterating from one code to another, exploring complex logical conditions imposed on the question and file, and probably many others, the automatic data-processing system offers the outstanding virtues of high speed and great versatility. Thus it is possible to use SEAC not only to test the utility of an automatic data-processing system for the Patent Office retrieval problem but also to study the performance of other devices by simulating them on SEAC. In the computing machine field it is a well-known phenomenon that machine users discover many new applications of these machines while they are in the process of using them. It is hoped that the experiments on SEAC will serve a similar purpose.

References and Notes

1. Because the search of Patent Office literature is such a complex task, we found particularly valuable the many informative discussions with members of the Office of Research and Development, U.S. Patent Office. In particular, their guidance helped to identify specific problem areas whose characteristics might be suited to machine processing and provided a background which led to a number of ideas that are contained in this article. In addition, fruitful discussions were held with Calvin N. Mooers of the Zator Co., whose helpful comments were derived from experience with related concepts in the field of information retrieval. The incentive to start on the computer search of chemical structures arose out of discussions with Ascher Opler of Dow Chemical Co. regarding his pioneering efforts with such techniques. Members of the Data Processing Systems Division of the National Bureau of Standards who contributed to the development of the results described here are Catherine E. Lester and Ethel C. Marden, who wrote the data-editing programs for SEAC, and Mary E. Stevens and Edwin K. Woods.
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Electronically Controlled Respirator

Randolph Batson, L. H. Montgomery, L. H. Beisel, David McCroskey, Sam L. Clark

The mechanical control of artificial respiration is customarily dependent upon devices regulated by an operator who adjusts the machine to supply an appropriate gas mixture, usually room air, at a previously determined rate, velocity, and volume. Although known norms and the reactions, subjective desires, and reflexes of the subject may be used to determine the effectiveness of the respiratory exchange, and although periodic chemical analyses of blood may offer further checks upon this, the patient or experimental animal has no direct control over the apparatus even though his nervous mechanisms are largely intact. Prolonged artificial respiration without frequent measure of arterial oxygen saturation, carbon dioxide tension, and blood *p*H may result in states of hyper- or hypoventilation.

The constant use of respirators by many patients with varying degrees of muscular paralysis following poliomyelitis emphasizes the need for some arrangement that would be less under outside control and more dependent upon the patient's normal physiological needs at any one moment. With this objective in mind, experiments were undertaken (*1*) to test the possibility of using the actual output of an animal's respiratory center as the source of impulses which would, through an appropriately designed electronic device, control mechanical respirators (*2*).

The first experiments were directed toward the utilization of the regular bursts of nerve impulses put out through the phrenic nerve in order to activate the diaphragm during the inspiratory phase of respiration. Because of technical difficulties, this plan was abandoned when it was found easier and more desirable to use potentials that accompany muscular contraction. Primary muscles of respiration such as the diaphragm or intercostals were found to be most effective in triggering the electronic device, but even minor accessory muscles such as the platysma or the small dilator of the dog's ala nasi have been used successfully, supplying effective control of respiration over periods of more than 48 hours in animals with high spinal transections. Successful control of respiration in anesthetized animals for many hours at a time has been readily obtained with needle electrodes in the ala nasi, the intercostals, or the diaphragm. Decerebrate cats have been maintained as long as 4 days without difficulty under electronic respiratory control.

Electronic Circuit

The electronic equipment was designed as shown in Fig. 1. It functions in the following way. Potentials from the muscle are picked up by 1- by 2-inch nickel silver electrodes on the surface of the skin or by needle electrodes implanted in the muscle and passed through an R-C filter to the input amplifier tubes. This stage of amplification is balanced so that it cancels in-phase voltages and amplifies the voltage difference between the two active electrodes. The combination of high-pass filter and degenerative

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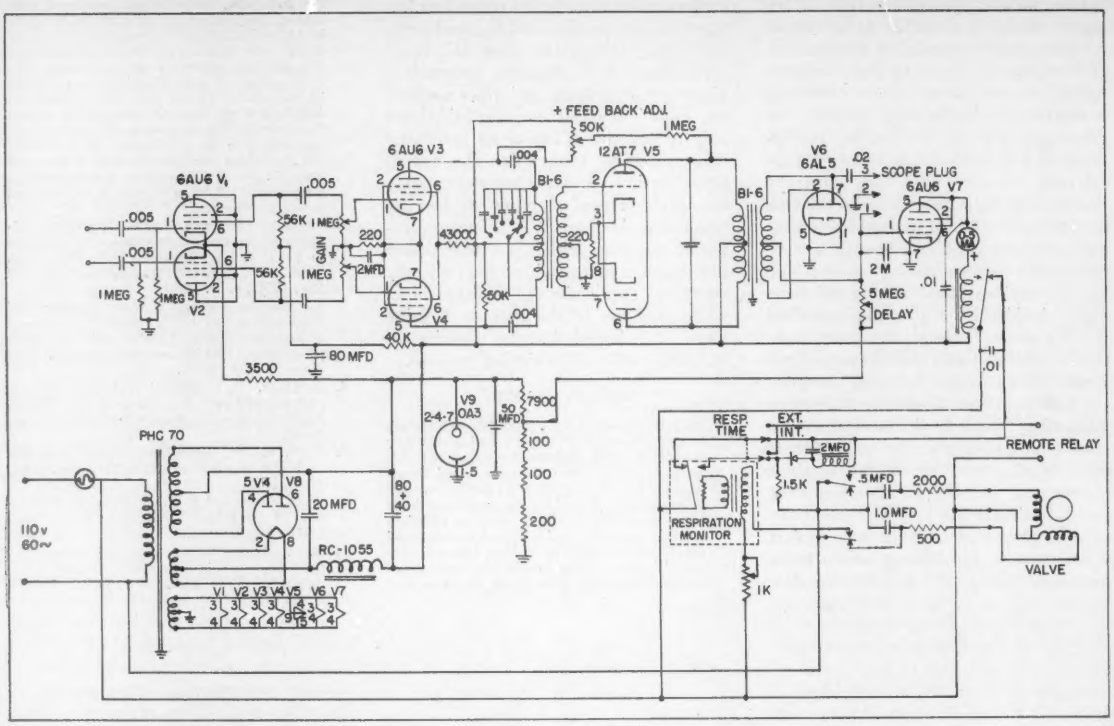

Fig. 1. Electronic circuits used to control the respirator.

input amplifier is quite effective in reducing artifacts (such as electrocardiograph potentials, stray 60-cycle-per-second, and other noise frequencies) to a value that is easily tolerated. The gain of the amplifier is adjusted to the optimum point by the attenuator between the first and second stages. By tuning the output of the second stage, the discrimination against interference may be further increased.

The filtered signal voltage is further amplified by the third stage, which feeds into an integrator circuit. The integrator produces a control voltage which is roughly proportional to the action potentials of the muscle in use. The integrated signal voltage is then further amplified by a d-c amplifier stage which in turn controls the action of the normal operational relay.

In the amplifier units designed for experimental use, a relay which operates a rotary solenoid valve controls the flow of air to and from the respirator. To provide an extra margin of safety, a monitor is included in the units intended for clinical use. This is designed to take over within defined limits the control of the respiratory cycle if the amplifier unit operation exceeds normal limits for the patient involved. Monitoring is accomplished by using an electrically heated wire, the thermal expansion of which is used to operate a contact-making lever. On this unit, when the normal operation relay contact closes for the inspiratory phase, a position relay which controls the solenoid valve also energizes a transformer that furnishes the heating current for the monitor expansion wire. The heating of this wire causes the lever to move away from the minimum respiration contact. During the expiratory and resting phase of the respiratory cycle, the current is shut off, and therefore the wire cools, causing the contact lever to float back in the direction of the low contact. Under normal operation the contact lever will float in the mid-scale range. In the event of muscle spasm, cessation of respiratory impulses; electronic failure, or other malfunction that might cause the equipment to remain on the inspiratory phase for an unduly long period, one of the range contacts will close, reversing the position relay and setting up an automatic respiration cycle which will continue until the patient resumes his normal efforts to breathe, or until the malfunctioning of the equipment is corrected. At this time the control of respiration automatically returns to the patient.

The basic principles involved in the design of this equipment have been carried over to the development of transistor models (*3*) which are planned for use with portable equipment and in situations (such as operating rooms) where the sparking contacts of the relays in the tube-type of equipment would be hazardous. In the experimental model a cathode-ray oscilloscope is customarily used to view the potentials used in the activation of the respirator.

Operation and Use

In the operation of the electronic respiratory control, some low frequency muscle potentials were sacrificed in order to obtain the smaller high-frequency components that are in a more desirable signal to noise ratio. The muscle potentials used exceed those of the artifacts in this mid-audio-frequency range. It was found desirable to make the amplifier tunable over the range from 100 to 1000 cycles per second since it was observed that the most reliable obtainable frequencies varied from patient to patient, being dependent upon the distribution and involvement of the neuromuscular units under investigation. The most troublesome interference, including the electrocardiographic potentials, is eliminated by filtering out frequencies below 100 cycles per second. Experience with the apparatus has shown that only a small percentage of the available potential has been required. It has also been observed

that animals appear to "learn" that the activation of the muscle being used is necessary to operate the electronic control; at least there is observed to be improvement in the process with use, in any individual experiment.

A sufficient number of experiments upon dogs have been performed to prove the efficacy of the device in allowing the animals' neurological and biochemical mechanisms to control their own respiratory needs. Through the electronic control, the animals used in the experiments made very rapid readjustments and quickly regained relatively normal blood values after the experimenter had by interference brought about for brief intervals extreme stages of hyper- and hypoventilation (*4*).

To date, experience with patients has been confined to testing the apparatus on partially paralyzed individuals who could stay out of a respirator for part of a day and who were interested in cooperating with the investigation. These patients have relied upon the electronic control for their respiration for periods of more than 24 hours at a time while under constant observation. This included long periods of normal sleep. During the time of use it was not necessary to adjust the skin electrodes or the controls of the electronic circuit.

The apparatus has been successfully used in both patients and animals to control pressure in tank and cuirass respirators, and to control pressure changes directly through the airway as in patients with masks and animals with intratracheal tubes.

It is obvious that this apparatus has other potentialities than its use with partially paralyzed patients. Already it has been used to map surviving muscles in such patients. As a laboratory aid in physiological research, it may be of advantage in studying problems dealing with neuromuscular function and pulmonary physiology. It offers promise of assistance in the control of inhalation anesthesia, particularly in operations in the open chest. It should be useful in the study of breathing patterns under a variety of conditions and in various diseases. It may offer aid to newborn and premature infants with respiratory distress.

References and Notes

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4. A detailed description of these experiments is in preparation.

Integrating Device for Use with Potentiometers

W. Keith Hall, Gustave Sill, Court L. Wolfe

An automatic recording potentiometer embodies a paper chart which is driven at constant speed in the *y* direction. Motion in the perpendicular *x* direction is accomplished by a potential which is usually simply related to a quantity which varies as a function of time and whose relationship to time is of interest. If, as in the case of gas-phase chromatography, the motion in the *x* direction is proportional to concentration, then the integral under the traced curve is proportional to the total amount—that is,

$$\text{Total amount} = c\int_0^\infty x\,dt$$

Similar and analogous situations exist in other types of work, such as spectroscopy, where the areas are required for quantitative analysis.

The use of gas-phase chromatography in research and in process control has been undergoing revolutionary development over the past several years (*1*). In some respects, this has altered the basic approach toward research. For example, the development of the microcatalytic technique (*2*, *3*) in this laboratory has accelerated catalytic research to such a degree that measurement of the chromatograms has become the slow step. That a similar situation exists in other laboratories is evidenced by the fact that it has become almost customary to evaluate these chromatograms by simply measuring peak heights rather than peak areas, in spite of the fact that this is an approximation and one that is particularly poor in the case of broad and asymmetrical peaks. Further, as noted earlier (*3*), one of the advantages of the chromatographic technique in the study of catalytic reactions is that the experimenter can obtain semiquantitative estimates of the results of an experiment as the experiment progresses and may be guided in his choice of the next step by the results already in hand. It was readily recognized, therefore, that even this situation could be improved if actual quantitative numbers were used to replace the visual estimates. It was on this basis that the development of the instrument described in this article was undertaken. Specifications for an integrating mechanism were drawn as follows:

1) The device was to operate in conjunction with the automatic recording potentiometer available to us (Leeds and Northrup Speedomax, 5-millivolt scale).

2) It should provide for the individual integration of each peak appearing on the chromatogram as it is drawn.

3) It should read out in digital form, totalizing to at least 99,999, to be stamped on a separate tape or else on the Speedomax chart adjacent to the integrated curve.

4) It should be reproducible to better than 1 percent.

5) It should provide for automatic clearing of the stored number after printing so that the integration of the next peak or following peaks will not be cumulative.

6) The pulse output rate at full-scale deflection on the potentiometer chart must exceed 1000 counts per minute to insure a sufficient number of significant figures per unit area. This condition amounts to asking that the device be capable of producing as many significant figures as are obtainable with a hand planimeter and with an accuracy as great as that of the average of several such determinations.

7) The device should be sufficiently intelligent to be able to distinguish between meaningful data and base line noise.

To the best of our knowledge, no commercial instrument presently available fulfills all the requirements listed. It was found, however, that an instrument satisfying these requirements could be made from commercially available basic components—namely, a ball and disk integrator supplied by the Librascope

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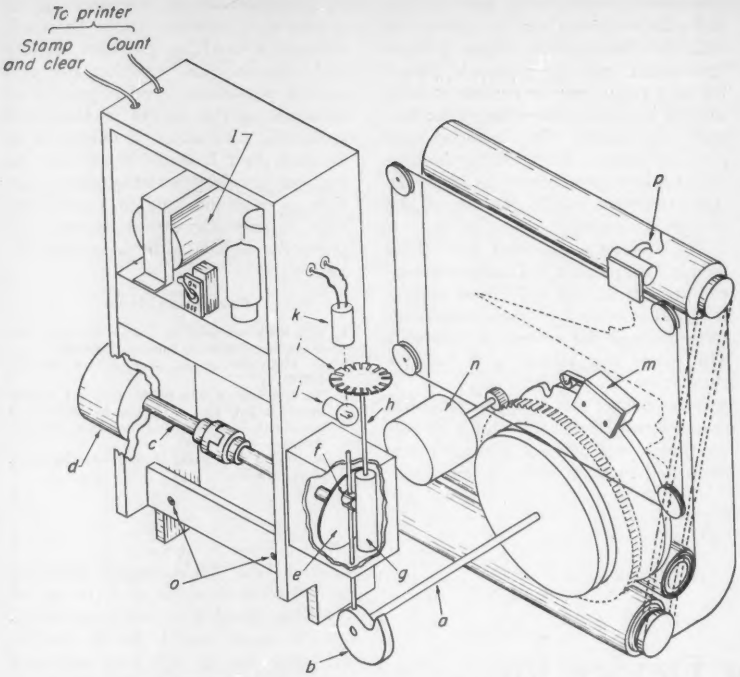

Fig 1. Schematic diagram of integrating mechanism: *a*, slide-wide shaft; *b*, linear cam; *c*, disk drive shaft; *d*, synchronous motor; *e*, disk; *f*, balls; *g*, output drum; *h*, output shaft; *i*, slotted disk; *j*, light; *k*, photocell; *l*, pulse-shaping and amplification circuit; *m*, integration base switch; *n*, balancing motor; *o*, screws holding unit to housing; *p*, pen.

Corporation; a 20-revolution-per-minute synchronous motor used to drive the integrator disk, supplied by the Hagen Manufacturing Company; and a pulse storage mechanism with a digital print-out supplied by the Streeter Amet Company. To these components it was only necessary to add a linear cam made in our shops, a photoconductivity cell actuated by light passing through a slotted disk, and a conventional pulse shaping circuit, which supplied the information in a square wave form to the pulse storage mechanism. In the latter connection, it should be noted that a scaling unit ordinarily used in connection with a Geiger counter replaced the Streeter Amet pulse storage mechanism in the early developments, before the latter became available.

Operation

The operation of the device starts with the principle used on the Fisher-Gulf partitioner, but provides digital print-out as well as greater resolution; it can be readily followed with reference to Fig. 1. The linear cam *b* is adjusted on the slide-wire shaft *a* in such a position that when the pen *p* is at the base line, the balls *f* are centered with respect to the disk *e* so that no motion is imparted to the output roll *g* in spite of the constant linear velocity of the disk, which is driven by the synchronous motor *d*. At this point, it is convenient to note that the rate of the rotation of the disk—that is, its radial velocity—is indirectly linked to the motion of the chart paper in the time direction, for both are driven by synchronous motors.

As the signal potential affects the balancing motor *n*, causing the pen to move in the x direction, the linear cam rotates, moving the balls out along a radius of the disk by an amount proportional to the displacement of the pen from the base line. Since the rate of rotary motion imparted to the roll by the balls, and hence the rate of rotation of the slotted disk *i*, is likewise directly proportional to the position of the balls along the radius of the disk, then the pulse rate supplied from the light source *j* to the photocell *k* is directly proportional to the displacement of the pen from the base line in the x direction.

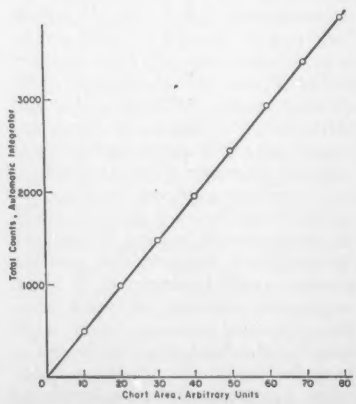

Fig. 2. Block area test of integrator.

The output of the photocell is fed into the pulse shaping and amplification circuit *l*, which is of a conventional design, but which employs a special high-speed mercury wetted relay supplied by the Western Electric Company. The output of this circuit is sent either directly into a scaling unit, in which case the summed counts are cumulative for the chromatogram and must be recorded by hand, or else into the Streeter Amet pulse storage unit until print-out is demanded by the closing of the limit switch *m* as the pen returns to the base line, when the integration ceases. Since the storage mechanism clears as it prints, areas for the individual peaks are recorded individually rather than cumulatively. In order to meet requirement 7, the limit switch *m* is positioned so that it allows the integration to begin when the pen has departed from the base line by about one-half of one division on a chart that has 100 divisions full scale and so that it allows integration to stop (and print-out to occur) under similar circumstances. (In this connection, it should be realized that a basic requirement that must be met before use of such an instrument is practical is that an extremely stable bridge circuit must be available. With the instrument described here, a set of Gow-Mac thermal conductivity cells and a conventional d-c cirucit powered by storage batteries were used. The carrying gas stream was split, and a slow purge was washed through the reference side independent of the measuring side, which was connected to the chromatographic column. With this arrangement, in a day's operation, any base line drift was within the limit of intelligence noted.)

One final comment seems justified. The linear cam faithfully produces a quantity proportional to the real area under the curve. By changing the shape of the cam, however, an automatic, mathematical transformation can be carried out. Thus for example, a logarithmic cam will produce $\int \log x \, dy$. This integral would be particularly valuable in spectroscopic work where x may be taken as I/I_0 (or $\log x$ as the optical density) and y may be taken as proportional to the wave length, λ. If the device were used

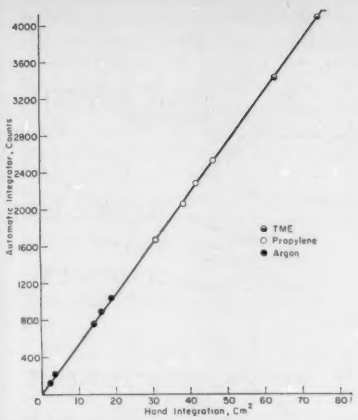

Fig. 3. Relationship between area of chromatogram and total pulse.

in this way, the analytic results could be printed out in digital form, vastly simplifying such work. It should also be noted that, if a situation should arise in which the data supplied by the integrator become a part of an elaborate and complicated calculation (as, for example, when a series of peaks from the same record are used to calculate the percentage composition of a complex mixture) then it would be possible to read out in punched-tape form, and the results could then be fed into a modern, high-speed calculating machine.

The total cost of material, labor, and so forth, exclusive of the cost of the recorder, is quite modest. This cost, however, could be reduced by a major fraction when the automatic printing and clearing features are not required. The instrument is, therefore, available to laboratories with very moderate budgets.

Accuracy and Repeatability

The accuracy and repeatability of the data are shown in Figs. 2 and 3, respectively. Figure 2 relates the number of pulses accumulated to the square area swept out on the chart; these data were obtained by using a scaling unit to totalize the number of pulses. The Speedomax was set with a millivolt source to run at a constant distance above the base line. The scaling unit and a timing clock were started and stopped simultaneously. During the elapsed time, a definite block of area was swept out on the chart as a function of the distance between the base line and the pen position. This area was plotted in arbitrary units against the total number of counts recorded in the 5-minute periods in Fig. 2. It can be seen that, on the basis of these square areas, the instrument gave perfect agreement. With the recorder used, it turned out that an arbitrary unit was nearly equal to 1 square centimeter, so that there is a close correspondence between the data plotted on Fig. 2 and on Fig. 3.

In Fig. 3, the results obtained from the automatic integrator for measurement of a number of calibration chromatograms are compared with the areas of the same peaks obtained using a B. K. Elliott hand planimeter. In these experiments, varying amounts of the several gases were passed through the column in a helium-carrying gas stream, and the response was recorded in the conventional manner. It should be emphasized that these data include results with three different gases: 2,3-dimethylbutane (tetramethylethane, or TME), propylene, and argon. The chromatographic peaks obtained for these were of vastly different shapes. The low-area argon peaks were extremely narrow and sharp. In fact, the areas are low because this gas was not held up in the column so that, even with a nearly full-scale deflection, the peak width at the base line did not exceed about 4 millimeters. The propylene peaks were still quite sharp, particularly on the front side, but were skewed by a moderately strong tail. Finally, the peaks for 2,3-dimethylbutane (TME) were very much broader than they were high. Thus, regardless of the shape of the peak, the automatic integrator appears to measure the area at least as accurately as hand integration.

This integrator can be made as an effective unit from known and available items, and we believe that its simplicity and convenience may make it useful to others.

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3. W. K. Hall and P. H. Emmett, *ibid.*, 79, 2091 (1957).

Automatic Particle and Bacterial Colony Counter

H. P. Mansberg

It has long been recognized that the counting of bacterial colonies on culture plates is one of the more tedious tasks performed in bacteriological laboratories. Many thousands of culture plates are counted daily in hundreds of dairy, food-industry, water-testing, pharmaceutical, and other laboratories throughout the country. In this era of electronics and automation it would appear surprising to many that automatic devices to perform this task have not been available.

Some of the standards and techniques that have evolved in bacterial assay tests are necessary compromises determined by the limitations of laboratory personnel in visual counting methods. These limitations include the inaccuracies of human counting, the inconsistencies between observers, and the high cost of both preparing and counting large numbers of samples. Quite possibly, if accurate automatic counting devices had been available before the evolution of bacterial assay standards, these standards would specify greater sampling quantities. For example, at present it is not at all unusual to find a fluctuation of 100 percent in the number of colonies from presumably identical aliquots of milk and cream (*1*). Where only one or two plates are now required by standard tests, with consequent poor sampling, the number of samples would be increased if the time and cost of preparation and evaluation were less.

Although many mechanical and visual aids have been proposed and constructed

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for assisting the laboratory technician in performing these tasks, these aids generally do not provide a really significant reduction in counting time, nor do they reduce sufficiently the variability of human error. As a first attempt in this direction, workers at the Allen B. DuMont Laboratories developed the automatic bacterial colony counter described in this article (*2*) for the U.S. Army Chemical Corps.

Principles of Design

The primary objective sought in the development of the bacterial colony counter was a scanning device which would be faster, more reliable and consistent, and, if possible, more accurate than laboratory technicians. Throughout the development, tests were made using both simulated and live cultures on standard 100-millimeter plates. The final design of the machine is shown in Fig. 1. Petri dishes that are inserted into the counting chamber of the machine are scanned by a cathode-ray tube and optical system. The scanning action is similar to that used in television, using a linear raster, except that a field is scanned at a much slower rate (one field per second). A pattern of 1000 lines traverses the dish once per second to obtain a resolution exceeding that of conventional television. A schematic representation of the optical system is shown in Fig. 2.

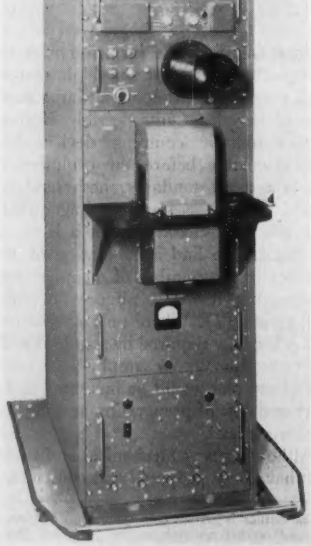

Fig. 1. Automatic particle and bacterial colony counter.

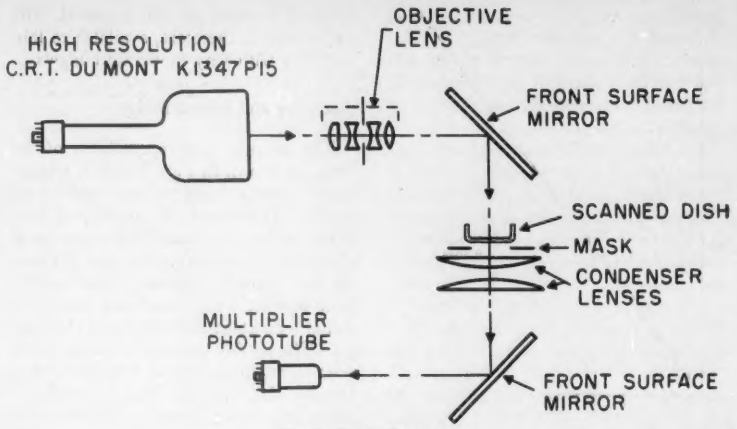

Fig. 2. Optical system.

The scanning spot produced by the cathode-ray tube is imaged, by means of an objective lens, on the agar surface of the culture dish. Light from this moving spot is transmitted through the dish and is collected by the condenser lenses, which in turn produce a disk of illumination on the photocathode of the multiplier phototube. The mirrors shown in Fig. 2 were used to fold the light path for convenience of mechanical design. Each time the scanning spot is occulted by an opaque or semiopaque colony (or any other particle), a pulse is produced by the phototube. The pulse width or duration is proportional to the chord length or intercept produced by traversing the colony. When a large number of closely spaced scanning lines is used, it is obvious that the number of pulses produced will be proportional to the sizes of the colonies, as well as the quantity. Since bacterial colony dimensions vary greatly with species, incubation time, and many other factors, an average colony diameter cannot be assumed. If such an assumption were valid, it would be a simple matter to calculate the quantity from the number of intercept pulses and the mean diameter.

Techniques for scanning and counting blood cells, using apertures and slits of successively different sizes to obtain statistical counts, have been used by Lagercrantz and others (*3*). Another technique, described by Roberts and Young, for a flying-spot microscope, uses a dual-spot scan to prevent multiple counting (*4*).

The instrument described here, illustrated by Fig. 1 and the operational block diagram of Fig. 3, uses a memory system to prevent multiple counting, regardless of colony size. This is accomplished by storing all the pulses on each scanning line for the total duration of one scan-line interval and comparing these pulses with any produced by the next successive scanning line. The logic of the circuits is such that, when the scanning spot intercepts a colony for the first time, a count is produced; but when the spot, on its next scan, intercepts the same colony, the stored or delayed pulse from the first intercept locks out and prevents additional counts. The delayed and undelayed pulses are compared on a time-overlap basis so that all other colonies resolved by the system are properly counted. Although the complete functional block diagram is shown in Fig. 3, only a very brief explanation of circuit operation is given and the reader is referred to other detailed discussions of the design (*5*).

The pulses produced by interception of the scanning spot with a colony are amplified and shaped to correct for certain optical and electronic distortion effects and passed to a delay circuit. The undelayed signal and the delayed signal are then both coupled to an anticoincidence circuit which performs the logic of first-intercept-recognition mentioned previously. The output of the anticoincidence circuit consists of one pulse for each colony. Each of the pulses is fed to a digital electronic counter which totals the count for one complete field scan.

The rest of the circuits shown in Fig. 3 provide for deflection of the scanning cathode-ray tube and of a monitor-display cathode-ray tube. The monitor-display tube presents a picture of the culture plate to the operator and facilitates proper adjustment of the machine in accordance with the types of specimens scanned. For example, certain types of culture medium may be extremely dense optically, so that a compensating adjustment of the sensitivity of the phototube or the brightness of the scanning spot may be required. Frequently the culture plate contains very small contaminants or dirt particles which cause extra counts. Under certain conditions

the display monitor also facilitates the making of compensating adjustments for this condition. Finally, the visual display monitor allows the operator to determine, at a glance, whether all the colonies are being detected and counted. The display monitor produces an image of each colony on the screen with a small bright checking dot superimposed at the top of each colony as it is electronically counted. A typical display of a scanned culture dish is shown in Fig. 4.

Evaluation of Machine Performance

Before presenting evaluation data on the performance of the machine, it would be well to describe briefly the basic capabilities and limitations determined by the present design. The size of the smallest colony that can be detected is determined primarily by the diameter of the scanning spot. In scanning a 100-millimeter diameter culture dish, colonies down to 0.5-millimeter diameter can be detected and counted reliably. Optical defects in the glass or agar, or contaminants, if large enough to be resolved, cannot be distinguished from colonies by the machine. If present, these defects and contaminants increase the count. It should be pointed out that a human observer, too, is frequently inaccurate in his count because of such factors.

Colonies which are contiguous and clump together are recognized by the machine as individuals only if they are oriented so that they present individual tangencies to the intercepting scanning lines. This effect can be observed on the picture display of Fig. 4. Note that colonies that are vertically contiguous produce only a single bright counting mark, while other contiguous colonies are registered properly. Here again, the technician performing visual counts may err in his judgment concerning clumped colonies, although not to the extent of the machine, which has no judgment.

Correction factors for contiguity can be derived by statistical methods when large samples of particular species of bacterial cultures are run. Care in the inoculation of culture plates and a reduction in incubation time, where possible, minimize contiguity. Care should also be exercised to prevent spreading the inoculant to the extreme edges so that colonies grow on the meniscus or sides of the culture dish. The glass-bead rim of molded petri dishes necessitates optical masking of the extreme edge of the dish in the machine. With poured plates this factor cannot be controlled, but statistical correction factors can be applied.

Finally, with regard to performance capabilities inherent in the technique, it should be realized that the machine is not subject to fatigue and that it is therefore far more consistent on repeated sampling than are human observers.

Before acceptance of the machine by the Chemical Corps, extensive evaluation tests were performed in their laboratories. The data obtained during these tests are not available for publication, but it may be stated that the results have been very satisfactory for their particular requirements. The major limitation to counting accuracy has been contiguity, as anticipated, but correction factors for some bacteria species have been derived.

Performance tests have also been made at the DuMont laboratories and at two dairy laboratories. Typical test data obtained at the DuMont Laboratories with cultures of *Serratia marcescens* on peptone agar are shown in Table 1. In performing these tests, the machine scans and registers a count every 2 seconds, while it takes a technician approximately 2 minutes to obtain a count by normal methods.

Table 1. Typical machine versus visual counts.

Plate No.	Visual count	Machine count
1	24	24
2	39	40
3	42	45
4	44	48
5	49	55
6	19	23
7	17	20
8	40	42
9	16	20
10	23	24
11	45	47
12	40	48
13	30	33
14	109	107
15	84	86
16	122	120
17	140	135
18	181	160
19	194	151
20	247	241
21	166	150
22	492	437
23	529	439

Data such as those given in Table 1, obtained from routinely prepared plates, show that the relationship of machine count to technician's count is a function of plate population density. At low densities the automatic count tends to be higher than the technician's count, whil at high densities the machine count runs 80 to 90 percent of the visual count. Study has shown that the causes of this bias are as follows: (i) High counts at low densities are caused by a few contaminants and defects in the glass and agar which are significant at low densities. (ii) Low counts at high densities are primarily caused by a large percentage of contiguous colonies. (iii) Low counts at high densities are caused, to a lesser extent, by the presence of colonies at the periphery of the dish which are not scanned by the machine.

Another condition which should be recognized is that it is common practice in counting high-density plates for a technician to count only a portion of the total area and then to estimate the total by the ratio of areas. The repeatability of technicians' counts is therefore very poor, and the variation between different technicians counting the same high-density plate is substantial. Typical variations and spread in technicians' count versus spread in machine count for repeated tests are shown in Table 2. These data

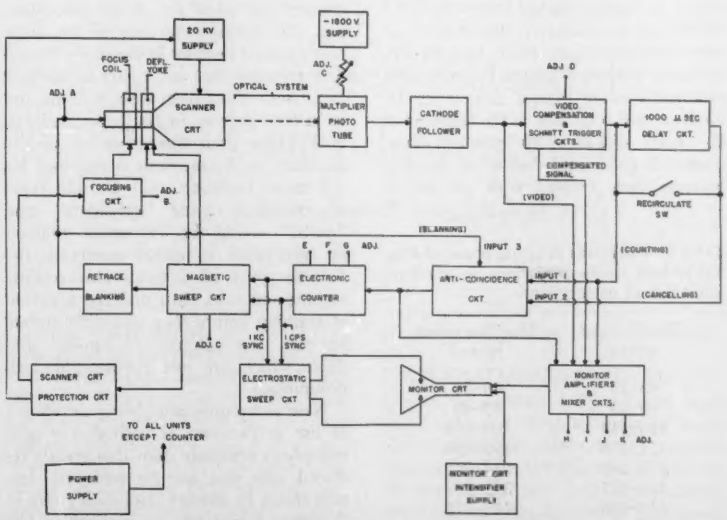

Fig. 3. Electronic scanning and counting system.

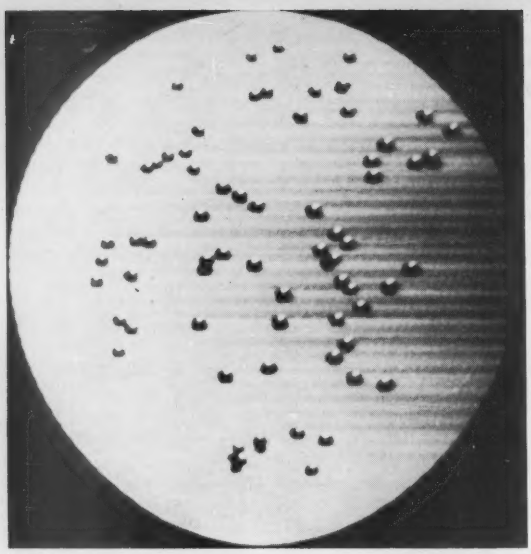

Fig. 4. Monitor picture display of a culture plate being counted.

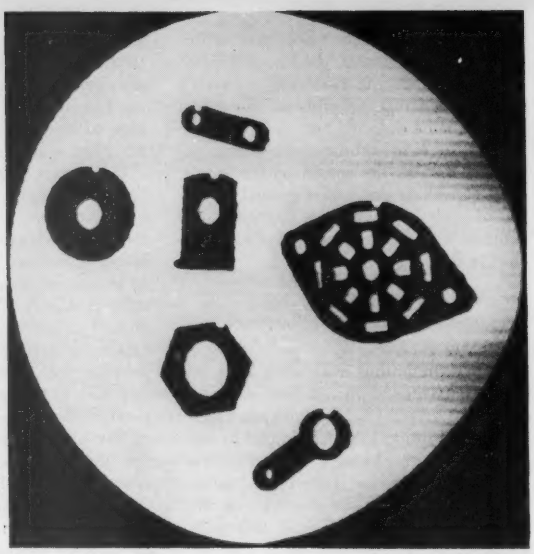

Fig. 5. Monitor picture display of assorted pieces of hardware being counted.

were obtained by visually counting incubated culture plates using four different observers and then counting each plate in the automatic counter using four different orientations with respect to the scan direction.

While the average machine count is frequently considerably less than the average visual count for normally prepared culture plates, it was found to be much more consistent. The automatic colony counter was sensitive to orientation of the culture plate because of the effect of colony contiguity. Since the colonies are randomly oriented with respect to clumping, no orientation could be found which would yield the true count. The machine was very consistent in repeated counts when the plate was kept in a fixed position.

Tests with simulated colonies on a plastic base, where no glass defects or contiguity were present, gave extremely accurate results. As an example, a specimen was prepared using a photoengraver's half-tone screen containing 2500 opaque dots 0.5 millimeter in diameter. The machine was able to produce counts of 2500 consistently for many hours. The addition of a single particle of material into the dish produced a count of 2501. The inherent accuracy of the machine is therefore 100 percent under ideal conditions. This suggests the desirability of improving the techniques of culture-plate preparation in order to realize fully the advantages of automatic colony counting. On the other hand, it is realized that the use of greater care in the preparation of cultures may offset the economies achieved by automatic counting.

An evaluation of the instrument's usefulness in routine dairy laboratory bacterial colony counting was undertaken at the Sealtest Supplee Laboratory of Philadelphia and at the New Jersey Dairy Laboratories of New Brunswick (*6*, *7*). Present dairy laboratory counting procedures require that extremely small, pin-point colonies be counted in order to minimize incubation time and to supply rapid sample evaluation. Dairy culture plates usually contain a very large percentage of colonies 0.1 millimeter in diameter. Since the machine was designed to count colonies larger than 0.5 millimeter in diameter, the results of these tests were quite poor. In addition, routinely prepared plates in most laboratories contain optical defects in the medium and scratches in the bottoms of the petri dishes; both produce false counts. It was found that when the dish bottoms were treated with oil and a layer of water was poured on the surface of the agar, these errors were reduced. An experimental modification of one machine was made, to reduce the area of the dish scanned, so that a smaller scanning spot could be realized. Subsequent tests showed that, with this modification, colonies 0.1 millimeter in diameter could be detected and counted. However, the same difficulties previously noted with clumping or contiguous colonies occurred.

Table 2. Variations in visual count of four technicians versus variations in machine count in four orientations.

Visual count spread	Machine count spread
43–48	48–53
49–55	43–49
110–118	104–108
191–239	190–196
249–309	233–243
375–477	333–347
444–498	403–419

As a result of these dairy laboratory tests, the following conclusions were reached. (i) Substantial improvement in scanner resolution is required in a colony counter intended for dairy laboratory use. (ii) Satisfactory use of an automatic colony counter in the dairy laboratory requires that more care be used to avoid scratching petri dish bottoms and to reduce defects in the agar medium. (iii) More even dispersion of sample dilutions in the medium is required for automatic counting. (iv) Certain types of colonies, called "spreaders" and "pulls," would be extremely difficult or impossible to count automatically. (These types of colonies also confuse technicians, who must undergo a period of training before they can differentiate between the colonies of "pulls" and those which are not portions of such groupings.)

New techniques now being developed in the preparation of cathode-ray tube phosphors definitely show that greatly reduced spot size can be achieved. Improvement in scanner resolution (item i) therefore appears to be realizable. The

difficulty in handling described in item ii can be overcome by the use of oil treatment of the glass or by improved handling techniques. A step in the direction of solving the problem of item iii has been taken by the New Jersey Dairy Laboratories, which uses mechanical rotation of dishes during preparation to improve distribution. Most laboratories employ manual rotation of petri dishes, but the colony distribution so produced is poor. Building sufficient logic into a scanning machine so that it can count "spreaders" and "pulls" properly appears, at present, to be prohibitively expensive.

Other Applications

The scanning and information processing techniques used in the automatic particle and bacterial colony counter are applicable to many problems involving the analysis of a small or large visual field. For example, any objects that can be placed in a petri dish may be counted, provided that they are sufficiently large to be resolved (0.5 millimeter in diameter). Figure 5 shows an assortment of electrical hardware components being scanned and displayed on the monitor. The bright counting dot at the top of each item shows that it was properly counted and that the instrument was not "confused" by its shape or the presence of holes. Modified versions of the instrument have also been used with equal facility to count bacterial colonies on opaque membrane filters and pinholes in opaque metal foils. Although demonstrations of these capabilities have been impressive, no single version of a flying-spot scanning device can be versatile enough to handle all of the problems requiring optical scanning. Some applications require the scanning of very large areas, and others require the scanning of microscopic areas. Furthermore, many scanning applications require logic circuitry to provide size and area, density, spectral, and other types of information. This means, of course, that different optical and electronic systems must be developed for the basic flying spot scanner-phototube combination to apply it to these problems.

A whole new field of industrial instrumentation involving the use of flying-spot scanners for automatic flaw inspection of large-area sheet products such as paper, glass, metal, and foils appears to be imminent (*8*). At the other extreme, with respect to size of area scanned, flying-spot microscopes are being developed in this country (and are commercially available in England) to perform such functions as the counting and sizing of microparticles. One of the most significant contributions to biological research, in the field of cell and tissue studies, has been the development of an ultraviolet flying-spot microscope. This instrument, developed at the University of Texas Medical School, has permitted, for the first time, the unlimited study of living cells with ultraviolet light (*9*).

It is believed by many that the flying-spot microscope, when equipped with special information-processing circuits such as those of the automatic colony counter, will provide a very powerful tool for industrial and biological research laboratories. Accordingly, it may be destined to follow a path of development, requiring evolution of techniques and accessories, analogous to the path of the development of the electron microscope. The automatic particle and bacterial colony counter should be considered, therefore, to be one step in the development of flying-spot, optical-electronic transducer instrumentation.

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2. This work was sponsored by the U.S. Army Chemical Corps. I appreciate the guidance of Nelson E. Alexander of the U.S. Army Chemical Corps. Credit is due, too, to the successful efforts of the engineering group at the Allen B. DuMont Laboratories in the development of this instrument. The evaluation of the dairy application was made possible by the cooperation of David Levowitz, director of the New Jersey Dairy Laboratories, and B. A. Larsen, director of the Sealtest Supplee Laboratory.
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Servo Control of General Anesthesia

J. Weldon Bellville and George M. Attura

The automatic control art with its associated servo machines offers a finer control of physical variables than can normally be accomplished by human operators. This holds true for complex military devices as well as for those automatic control systems that have been introduced into the field of medicine. We have developed a servo control mechanism that will control a single physiological process, depth of anesthesia.

Regardless of its application, the quantity to be controlled by a servo must fulfill certain criteria. It must be measurable by some data-sensing element which translates the quantity in test into an electric voltage, and motor means must be available to control this quantity.

In the field of anesthesia, we have a situation that will fulfill these criteria. The depth of anesthesia is the quantity that must be controlled. For our purposes, we can define depth of anesthesia in terms of the cortical potential that is recorded by an electroencephalograph. The deeper the level of anesthesia, the less the electric cortical potential. If increasing concentration of anesthetic in the blood parallels increasing depth of anesthesia, then this premise is valid, since it has been shown that there is an inverse relationship between the concentration of ether or cyclopropane in the blood and the electroencephalograph potential (*1*, *2*). The depth of anesthesia is usually controlled by the amount of anesthetic agent administered to the patient per unit time, whether the agent

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is a barbiturate given intravenously or a gas which the patient is allowed to inhale. Since the depth of anesthesia can be measured as an electric quantity, a suitable servo device can be placed between the electric variable and the pump or valve that administers the anesthetic to the patient.

Human Control

At present, during the majority of operations, depth of anesthesia is determined and controlled by an anesthesiologist who observes the patient. The anesthesiologist gages the depth of anesthesia through his senses by considering the patient's respiratory rate, chest wall movements, muscle tone, blood pressure, pulse rate, pupil size, various reflex responses, and other general clinical criteria. Correlating these observations with his experience, the anesthesiologist estimates the depth of anesthesia at any given moment, and, considering the requirements of the surgeon, decides whether more or less anesthetic is necessary.

Of necessity, the process is not completely continuous. A correction is applied to the rate of administration of anesthetic agent to the patient, and, at varying intervals, the clinical observations are repeated, and the rate of administration of the anesthetic is again readjusted. There exists, thus, a cause-and-effect relationship between the anesthetic agent and the clinical signs of the patient. This relationship, together with interpretation and control by the anesthesiologist, constitutes a loop or chain of response (Fig. 1*a*).

It is important to note that the situation described is a true feedback control system in which both the patient and the anesthesiologist play important functions. It might be called a human servo, since the action of the anesthesiologist is determined by his observation of the effect of his previous actions in adjusting the rate of administration of anesthetic agent. Thus, it is in the same servo class with other automatic-control and feedback-control systems in current use in industry and elsewhere, except that the interpretation of data and the motor action to control the output physical variable are performed by the human operator, namely, the anesthesiologist.

In subsequent paragraphs, it is shown that the addition of a servo device does not change the nature of this loop, but merely improves its accuracy and speed of response. The addition of the anesthesia servo device to this feedback loop can improve it in two major respects. First, the accuracy of sensing the depth of anesthesia can be increased and, second, the time interval necessary to sense and correct the depth of anesthesia can be reduced. These two factors combined result in an accurate, uniform control of anesthesia.

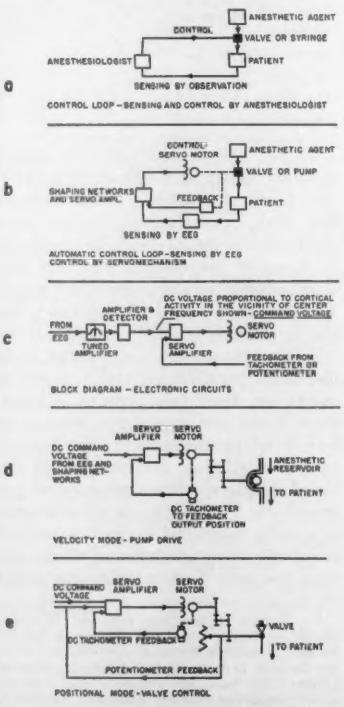

Fig. 1. Feedback loops.

Servo Control

The first system designed to control the depth of anesthesia automatically was described by Bickford in 1950 (*3, 4*). Sensing the depth of anesthesia was accomplished by noting the output of an electroencephalograph, and a fixed amount of Pentothal or diethyl ether was administered automatically in response to the integrated cortical activity. In 1952, Bickford described frequency discrimination to sense depth of anesthesia more accurately (*5*). The continuous automatic control of cyclopropane anesthesia was described in 1953 (*6*). Recently, it has been shown by electroencephalographic frequency spectrum analysis during anesthesia that the amplitude of certain frequency bands varies with the depth of anesthesia (*7*).

When the electroencephalograph is used to monitor a selected cortical frequency, its output becomes an accurate index of the depth of anesthesia. This electric voltage, properly processed and transformed, can be used to drive a servo mechanism which controls the flow of anesthetic to the patient as a direct function of the voltage. A simple block diagram of the servo-driven anesthesia system is shown in Fig. 1*b*. The electroencephalographic output is fed to a band-pass network whose output in turn contains only those frequency components from the electroencephalograph which are close to the chosen frequency. Roughly speaking, if the frequency is properly chosen, the lighter the anesthesia the greater the electric output from this band-pass circuit. This voltage, then, can be considered proportional to the level of wakefulness of the patient and inversely proportional to the depth of anesthesia. This voltage is spoken of hereafter as the "command voltage." The servo system between the command voltage and the anesthetic consists of a motor driven by a servo amplifier whose input is the output of the band-pass circuit, the command voltage (Fig. 1*c*).

If the anesthetic is to be administered intravenously, as is the case with Pentothal, the motor drives a positive displacement pump at a speed which is very closely proportional to the command voltage of the servo (Fig. 1*d*). In this mode of operation, we have what is called a "velocity servo," since the velocity of the output shaft is proportional to the command voltage.

If the anesthetic is a gas, a valve is used to control its rate of flow to the patient who is inhaling it. In this case, the servo must establish correspondence between the position of the valve and the command voltage. Here a type of servo commonly called a "positional servo" is employed. For a positional servo, the output voltage from the band-pass network—the command voltage—determines the instantaneous position of the valve (Fig. 1*e*).

It is important to note again that the use of a servo device does not basically alter the loop that exists when the anesthesiologist is performing the sensing and control functions. As has been explained, in that case we do have a feedback loop, with the depth of anesthesia of the patient acting as the controlled quantity and with the anesthesiologist, with his equipment, performing the dual role of sensing and controlling (Fig. 1*a*). In the new system, the servo device substitutes for the anesthesiologist; sensing the depth of anesthesia is a function of the electroencephalograph and its associated band-pass networks, and controlling the depth is a function of the servo motor and its associated mechanism. The only reason for introducing this change is to achieve a system capable of greater precision of control and greater speed of response—a system free from human error.

Description of Servo and Modes

The system described in this article has been developed by us to administer Pentothal, cyclopropane, or ether by

means of servo techniques. The electroencephalogram is obtained by inserting No. 25 needle electrodes into the scalp overlying one hemisphere in a frontocentral position. Records are made on a Grass IIID electroencephalograph whose frequency response is flat from 1 to 40 cycles per second. The output from the electroencephalograph is fed into tuned band-pass electronic networks which pass only frequency components close to the tuned frequency. For this system, there are two networks: one tuned to 24 cycles per second for ether anesthesia and one tuned to 16 cycles per second for Pentothal or cyclopropane anesthesia. The proper network is selected by a switch (*S*1, Fig. 2). The band-pass circuits are shown in the accompanying schematic diagram (Fig. 2). The band-pass stage is a tuned amplifier (*V*1) with parallel-T feedback which results in a precisely known and shaped band-pass characteristic. The center of resonant frequency is determined by the values of the resistors and condensers in the tuned parallel-T feedback circuit. The output of the band-pass stage is fed to another amplifier and then rectified into a d-c voltage which varies linearly with the output of the band-pass network, and hence follows proportionately the level of wakefulness of the patient, and therefore, inversely, the depth of his anesthesia.

Whether the servo is used in the velocity mode or in the position mode, the command voltage determines how fast the motor will turn the pump to administer the intravenous agent or the position of the valve for gaseous agents. The command signal then drives a closed servo loop consisting of a motor, tachometer, and amplifier (in the velocity mode) (Fig. 1*d*) or a motor, tachometer, potentiometer, and amplifier (in the position mode) (Fig. 1*e*).

In the velocity mode, the proportionality between output velocity and command voltage is obtained by feeding back from the tachometer a d-c voltage proportional to the velocity and comparing it with the command voltage. The difference between these two, which is a very sensitive measure of the error, then drives the servo amplifier and forces the motor, tachometer, and pump to follow at a speed which is very precisely proportional to the command voltage and hence to the level of wakefulness of the patient.

In the positional mode, the command voltage is compared with a d-c voltage from the wiper of a potentiometer which is coupled to the moving part of the gas valve. Driven by the error between these two voltages, the servo system turns the motor, pump, and potentiometer until the potentiometer potential is exactly equal to the command voltage. At this point, the error between the two voltages is zero. The servo motor stops. In this way, exact proportionality between valve position and command voltage or level of wakefulness of the patient is obtained. Since the valve position bears a proportional relationship to the volume of anesthetic gas, the level of anesthesia in the patient is brought under control.

The tachometer is also retained and driven in the positional mode, although its function is different from its function in the velocity mode. In general, the positional servo is more subject to loop oscillations or "hunting" than the velocity servo. In this mode, the anesthesia servo would hunt uncontrollably around its null unless some means of damping were provided. A convenient damping technique is to feed back to the input of the servo amplifier a voltage obtained from the output shaft. The tachometer voltage is then used to damp the loop in the positional mode.

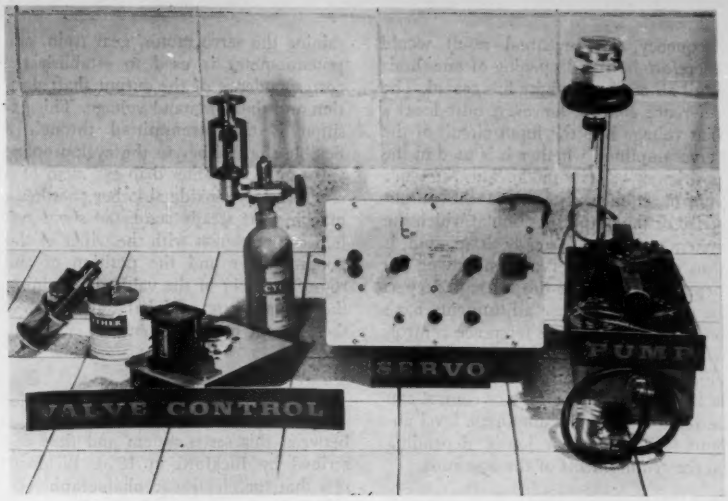

Fig. 3. Servo control unit with pump drive and valve control.

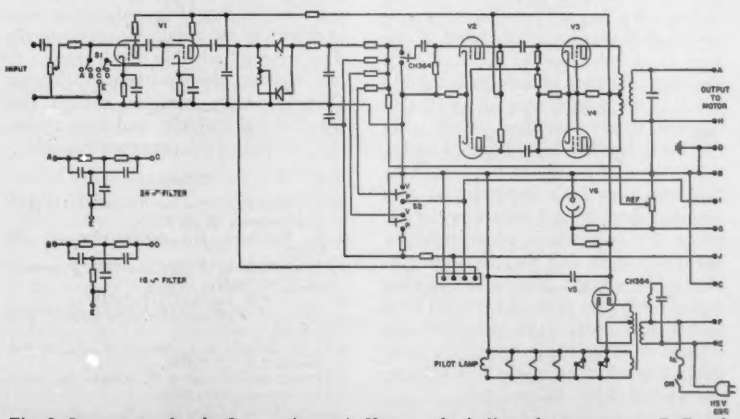

Fig. 2. Servo control unit. Connections: *A*, *H*, control winding of servo motor; *E*, *F*, reference winding of servo motor; *G*, *I*, *B*, potentiometer; *C*, *J*, tachometer.

Depth Control

With the circuit shown (Fig. 2) it has been possible to combine these two functions in a single apparatus using the same servo amplifier. The transition from velocity mode to position mode is made by turning a switch (*S*2, Fig. 2) on the front panel (Fig. 3) and connecting a cable to the appropriate pump or valve control.

A very important feature of this instrument is the addition of a threshold level control which sets the reference level against which the system operates (*REF*, Fig. 2). The reference level determines the steady-state depth of anesthesia of the patient. Without this control, the action of a servo system would continue the flow of anesthetic to the patient as long as there was any electroencephalographic activity at the selected

frequency. The eventual result would therefore be the deepening of anesthesia until all cortical activity has ceased. The reference control, however, introduces a bias voltage into the input circuit of the servo amplifier, whether it is used in the position or velocity mode. This reference control voltage determines the output speed or the output position at which the system achieves a steady state, and it thus prevents the servo from driving the depth of anesthesia deeper and deeper. In practice, all other adjustments have been made so that this reference control, with its calibration on the front panel (Fig. 3) determines the anesthetic level of the patient. The reference control can be reset to bring the anesthetic level automatically higher or lower, depending on the requirements of the operation.

Motor Means

As has been mentioned, the servo motor will drive either a pump or valve through associated gearing. One successful form of a pump drive is shown in Fig. 3. The servo motor and tachometer are geared down 300 to 1 to drive the rotor of the positive-displacement pump. This pump has been adapted from a peristaltic action pump manufactured by the American Instrument Co. It consists of a constrained half-turn of flexible tubing through which the liquid intravenous anesthetic is forced by the action of rollers which press the two walls of the tubing together and hence force the anesthetic to move in one direction with a volume rate of flow proportional to the speed of the rotor of the pump. In this application it is important that a positive-displacement pump be used, for the following conditions must be met: (i) a definite correspondence must exist between the volume of fluid injected and the displacement of the pump rotor; (ii) there must be no change in the rate of fluid flow with changes in venous pressure; (iii) there must be no change in the rate of fluid flow with the change in hydrostatic pressure between the pump and reservoir. A positive-displacement pump, as its name implies, resolves all these difficulties, and this particular pump has proved to be quite successful for this application. This pump also has the distinct advantage that sterility is not a problem, since sterile intravenous tubing can be made to fit it (Fig. 3).

For gaseous anesthetics, a different system must be used. It is necessary to control the position of a valve and to keep it in tight correspondence with the rectified monitored output of the electroencephalograph—the command voltage. In our application, a gear box containing the servo motor, gear train, and potentiometer is used to establish the correspondence of the output shaft position and the command voltage. This position is then transmitted through a flexible shaft either to the cyclopropane valve or to the ether drip can stem of a circle carbon dioxide absorber anesthesia machine. At steady state, the servo system comes to rest with the wiper of the potentiometer and the position of the rotary member of the valve determining the volume rate of inhalation of anesthetic agent by the patient.

Discussion

It is important to note the difference between this servo system and that described by Bickford in 1950. Bickford saw that the electroencephalograph represented a more sensitive indicator of the depth of anesthesia than any available clinical sign. He used the rectified energy output of the cortex to charge a condenser with a d-c voltage. When this charge or voltage exceeded a certain value, it triggered a thyratron tube which in turn actuated a relay to inject a fixed volume of Pentothal. Later Bickford modified this system to include a bandpass stage to select only 12-cycle-per-second activity, since he found that the 12-cycle activity varies directly with the depth of anesthesia. The servo device employed by Bickford can be called an "on-off servo," for it lacks the proportioning feature discussed here. No Pentothal is injected into the patient until the integrated level of cortical activity exceeds a certain point. At this point the thyratron discharges, and the relay injects a slug of Pentothal into the vein. This increment of Pentothal, after a suitable delay, increases the depth of anesthesia, and the system remains dormant until the thryatron again discharges. It might be said that in this system the patient reaches a certain level of wakefulness, but that the machine senses it and injects a slug of Pentothal to increase his depth of anesthesia once more. If one were to plot the level or depth of anesthesia as a function of time for Bickford's machine, he would note an oscillation between deeper anesthesia right after the Pentothal has been injected and a lighter level of anesthesia just before the thyratron fires. It is important to note also that there is no feedback per se between the unit which administers the anesthetic agent and the electroencephalographic voltage. Hence, the calibration of the system or the time or the level at which it fires (and therefore the amount of Pentothal it injects) is a variable dependent on aging, line voltage, and several other factors.

The chief improvement of our present system has been the introduction of the feedback principle locally between the dispenser of the anesthetic agent and the output of the electroencephalograph. This local or secondary feedback loop, which is really the chief feature of the servo device we have described, serves only to set a precise calibration in the relationship between the electroencephalograph output and the amount of anesthetic agent that is introduced into the patient. A happy by-product of this type of system is that the action is continuous, and as such it can continuously readjust itself so that it maintains a constant depth of anesthesia within the patient instead of oscillating as an "on-off servo" does.

Present Application

The servo described in this article can be a valuable aid in pharmacologic evaluation of drugs. Some physiological responses such as pulmonary and vascular reflexes are dependent on the depth of anesthesia. Maintenance of a constant level of anesthesia eliminates this variable. If depth of anesthesia is controlled automatically, and if additional anesthetic is introduced as a disturbance factor, the response of the servo system will represent a measure of drug action. Thus, the relative potency of agents which affect the electroencephalogram can easily be determined. Other servo systems will undoubtedly be used in the future by the pharmacologist since they can be used to study drug action at or near equilibrium conditions.

Even though this servo device responds more quickly and controls depth of anesthesia more accurately than the human operator, it may be many years before these control instruments are widely used clinically. The anesthesiologist senses many variables and correlates his observations with past experience and the requirements of the surgeon in order to determine the anesthetic requirements. This servo is limited in that it senses only one variable, the electroencephalogram. Certainly more complex devices that sense several variables and have memories and fail-safe features are possible.

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Glass Electrode for Measuring Sodium Ion

George Eisenman, Donald O. Rudin, James U. Casby

In 1934, von Lengyel and Blum observed that adding the acidic oxide Al_2O_3 or B_2O_3 to sodium silicate glasses caused the glass electrode potential to become strongly dependent on the concentration of several cations besides H^+ (*1*). Their data indicated that the sensitivity probably ranked in the decreasing order H^+, Na^+, K^+ and Li^+. These observations suggested that practical glass electrodes might be developed for measuring the Na^+ activity as a continuous function of time in ionic mixtures and in biological fluids. Von Lengyel and Blum's observations have been confirmed and extended by us in a large number of electrodes made from several melts of their Du composition (SiO_2, 62 moles percent; Al_2O_3, 11 moles percent; Na_2O, 24 moles percent; CaO, 3 moles percent). In addition, we have studied the electrode potential as a function of systematic variations of glass composition in a number of simple glass systems. This article (*2*) is primarily concerned with some immediately useful consequences of the study of the ternary glass system, Na_2O-Al_2O_3-SiO_2 (*3*).

All glass electrodes containing more than a fraction of 1 mole percent of Al_2O_3 are markedly cation sensitive, and the sensitivity for different cations relative to one another is a systematic and reproducible function of glass composition (see subsequent paragraphs). In single cation solutions of H^+, Na^+, K^+, or Li^+, the glasses yield electrode potentials which are a linear function of the logarithm of cation activity with a slope of 58 millivolts for a tenfold activity change at 20° to 22°C when referred to a saturated KCl bridge calomel half-cell. When measured against a Ag-AgCl half-cell without liquid junction, the chloride salts give the expected slope of 116 millivolts. The glass electrodes are indifferent to the particular anion present (chloride, hydroxyl, bicarbonate, nitrate, acetate, carbonate, sulfate, thiosulfate, ferrocyanide, and ferricyanide were studied). They are not affected by the presence of oxidizing or reducing substances, for they have the same potential in thiosulfate as in chloride solutions, as well as in dilute solutions varying from 100-percent ferrocyanide to 100-percent ferricyanide.

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Electrode Potential

A precise description of the glass electrode potential in mixtures of any two univalent cations is given by the following new empirical equation.

$$E = E^\circ + \frac{RT}{F} \ln \left[(A^+)^{1/n_{AB}} + k_{AB}^{1/n_{AB}} (B^+)^{1/n_{AB}} \right]^{n_{AB}} \qquad (1)$$

Equation 1 not only describes all of our data, but appears to be quite general, fitting representative glass electrode data (*4–6*) examined by us. Parentheses around symbols denote activity; k_{AB} and n_{AB} are empirical constants for a given glass composition and cation pair (A^+, B^+) (*7*). Figure 1 (parts *A*, *B*, and *C*) presents representative data for the electrode potential in binary mixtures of H^+ and Na^+ (part A), H^+ and K^+ (part *B*), as well as in ternary mixtures of K^+, Na^+, and H^+ [at constant pH and (K^+)] (part *C*). The straight dotted line drawn through the triangles in parts *A* and *B* plots the potential recorded in pure HCl solutions of varying dilution (that is, at zero Na^+ or K^+) and has the expected slope of 58 millivolts per pH unit. The points in Figs. 1*A* and 1*B* are experimental values recorded as a function of varying H^+ activity with Na^+ or K^+ concentration constant at 0.1 molar. (Since H^+ never exceeded 10 percent of this amount, the ionic strength and the activity of Na^+ or K^+ were effectively constant.) The curves are drawn from Eq. 1 with the indicated values of n_{AB} and k_{AB}. Changes in Na^+ or K^+ produce appropriate shifts in the curves as described by Eq. 1. In the case of H^+–Na^+ mixtures, n_{HNa} generally equals 1 for sodium glasses sensitive to sodium ion, and Eq. 1 then takes a form which is the simplest case predicted by the theories of Dole (*5*) and Nicolsky (*8*), but for H^+–K^+ mixtures n_{HK} for many glass compositions is significantly greater than 1, approaching values as high as 3.5. If Eq. 1 is expanded as a series and the terms beyond the second are neglected, then it takes the form of Dole's and Wiener's modified electrode equation (*9*).

While the importance of Eq. 1 for this article is chiefly as an empirically valid representation of the experimental data, it should be mentioned that it can be derived thermodynamically by a treatment similar to Nicolsky's (*8*). Our derivation, however, requires the assumption that the activity of the adsorbed cations is proportional to the n^{th} power of their adsorbed amount rather than to the first power. This assumption also leads to a general adsorption isotherm mass action law):

$$k_{AB} = \frac{(A^+)\,(B^+_{ads.})^{n_{AB}}}{(B^+)\,(A^+_{ads.})^{n_{AB}}} \qquad (2)$$

where (A^+) and (B^+) are the ionic activities in solution, $A^+_{ads.}$ and $B_{ads.}$ are the mole fractions of A^+ and B^+ adsorbed, and k_{AB} and n_{AB} are the same constants as in Eq. 1. Equation 2 represents satisfactorily a wide range of ion exchange equilibria extracted from the literature (for example, synthetic organic cation and anion exchangers, natural and synthetic inorganic cation exchangers, as well as the binding of univalent anions to serum albumin). An equation of this form was first described by Kornfeld and Rothmund (*10*) as an empirical description of the ion exchange of permutites; but its possible extension to glass electrodes has not been recognized.

Although a general equation for tricationic mixtures has not yet been developed and tested, Eq. 1 has been found to describe the electrode potential in Na^+-K^+-H^+ mixtures when (H^+) is held constant and A^+ and B^+ represent Na^+ and K^+ (Fig. 1C, Fig. 2). In this case n_{NaK} is constant and equals 1 over a wide pH range (5.6 to 10.6) for representative glasses of our series. However, k_{NaK} varies with pH, approaching a constant value at high pH. (Examine Fig. 1*B* and 1*A* in this regard.) Figure 2 illustrates how k_{NaK} varies with pH for $NAS_{11\text{-}18}$ glass (Na_2O, 11 moles percent; Al_2O_3, 18 moles percent; SiO_2, 71 moles percent). At pH 10.6, k_{NaK} equals 3.48×10^{-3}, while at pH 5.6 it equals 1.06×10^{-2}.

Relative Sensitivity as a Function of Glass Composition

It is convenient and appropriate to define the "relative sensitivity" of a particular glass electrode for a given ion pair A^+, B^+ as equal to the value of k_{AB} since, above pH 6, n_{AB} may be taken as 1 for all ion pairs studied here, and k_{AB} does not differ greatly from its limiting value at high pH. (In this regard, note

the small deviation from the asymptote above pH 6 in Fig. 1*B*). For pH greater than 6, a value of k_{AB} of 0.01 signifies that 0.01 mole (A^+) is equivalent to 1.0 mole of (B^+) in determining the electrode potential. This simplification is useful because many potential measurements are needed in evaluating n_{AB}, while two measurements (one in pure A^+ of known activity and one in pure B^+) suffice for evaluating k_{AB}.

A study of relative cation sensitivities as a function of glass composition was made by direct comparison of the electrode potentials in 0.1*N* solutions of the single alkali cations at neutral pH as well as in pure 0.1*N* HCl solutions. Such a simple comparison has been found sufficiently accurate for the purposes of this article. Figure 3 summarizes the systematic and reproducible relationship found between glass composition (in moles percent of the oxides as determined by chemical analysis) and cation sensitivity to Na^+, K^+, and Li^+ relative to H^+ in *A*, *B*, *C*, and Na^+ relative to K^+ sensitivity in *D*. Contours of isosensitivity are plotted in the high SiO_2 corner of the triangular composition field for the Na_2O-Al_2O_3-SiO_2 system. For example, the 100-contour line in *D* traces all those compositions wherein NAS glasses are 100 times as sensitive to Na^+ as to K^+ at pH 7.6 (corresponding to $k_{NaK} = 0.01$). Figure 3 illustrates the fact that sodium aluminosilicate glasses can be made whose sensitivity for the alkali cations relative to H^+ can be varied from values smaller than 10^{-10} to values approaching 1 (*11*). In addition, the differential sensitivity for Na^+ relative to K^+ at pH 7.6 has been maximized at about 250:1 for the glasses it has been possible to make in this ternary system to date.

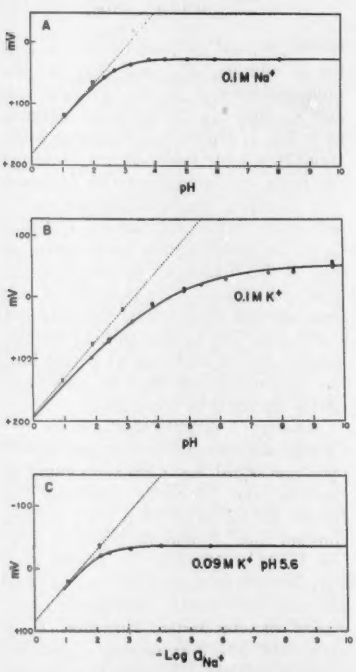

Fig. 1. Representative glass electrode potentials in ionic mixtures (Du glass). The solid curves plot the potential given by Eq. 1 for the indicated cation mixtures. The straight dotted lines plot the potential given by Eq. 1 for pure H^+ (*A* and *B*) and Na^+ (*C*) solutions. The points are experimental measurements referred to a saturated KCl-calomel half-cell. The abscissa in *A* and *B* was measured with Beckman pH electrodes. The abscissa in *C* was expressed as activity using 0.78 for the activity coefficient of the known Na^+ microcomponent concentration in the presence of a constant 0.09*M* K^+. The values of n_{AB} and k_{AB} used in drawing the curves were as follows: in *A*, $n_{HNa} = 1$, $k_{HNa} = 2.15 \times 10^{-2}$; in *B*, $n_{HK} = 3.5$, $k_{HK} = 8.86 \times 10^{-4}$; in *C*, $n_{NaK} = 1$, $k_{NaK} = 1.13 \times 10^{-1}$. The value of $2.303RT/F$ was taken as 58 millivolts at 22°C.

Applications

A glass having such a high selectivity for Na^+ relative to H^+ and K^+ offers an attractive device for measuring Na^+ activity in complex mixtures of ions. The best composition for many purposes is one which has the highest selectivity for Na^+ relative to K^+ and is also minimally sensitive to H^+. A comparison of Figures 3*A* and 3*D* indicates this composition to be Na_2O, 11 moles percent; Al_2O_3, 18 moles percent; and SiO_2, 71 moles percent ($NAS_{11\text{-}18}$ in our terminology). The composition of the initial mixture from which this glass was made was Na_2O, 11 moles percent; Al_2O_3, 27 moles percent; SiO_2, 62 moles percent. The approximate relative sensitivity of this glass to the various cations at neutral pH is as follows: H^+, 1; Na^+, 0.08; Li^+, 0.001; NH_4^+, 0.001; K^+, 0.0003; Rb^+, < 0.00002, Cs^+, < 0.00002; Ca^{++}, < 0.000015; Mg^{++}, < 0.0000004 (*12*). In good first approximation, one may obtain the relative sensitivity for any ion pair directly from these numbers (as discussed in 7).

In addition to the afore-mentioned measurements on the simple ternary system Na_2O-Al_2O_3-SiO_2, it has been found that adding small amounts of CaO or Fe_2O_3 to such glasses in quantities up to several moles percent does not alter significantly their electrode function. Presumably, this finding will permit the addition of small amounts of these and similar oxides to improve other physical properties of the glass. It has also been found that Na, Al, and Si per se are not needed in order that a glass may be highly cation sensitive, for Na_2O can be replaced by Li_2O or K_2O; SiO_2 can be replaced by GeO_2; and Al_2O_3 can be replaced by B_2O_3.

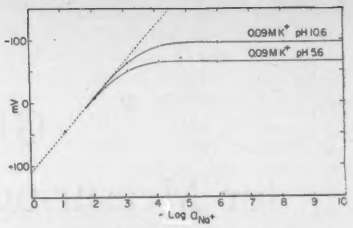

Fig. 2. Glass electrode potentials in Na^+-K^+ mixtures at pH 5.6 and at pH 10.6 ($NAS_{11\text{-}18}$). The solid circles are experimental points at pH 10.6. The open circles are experimental points at pH 5.6. The curves are again drawn according to Eq. 1 for $n_{NaK} = 1$, $k_{NaK} = 3.48 \times 10^{-3}$ at pH 10.6; and $n_{NaK} = 1$, $k_{NaK} = 10.6 \times 10^{-3}$ at pH 5.6

It can be calculated conservatively from the above data that, in biological fluids containing 0.15*M* Na^+ or more, an $NAS_{11\text{-}18}$ glass electrode would measure Na^+ activity with less than 0.2 percent error owing to the presence of an unknown K^+ concentration up to 30 m*M* at any pH higher than 5.6. Since $NAS_{11\text{-}18}$ glass is also relatively insensitive to Ca^{++} and Mg^{++} as well as to NH_4^+ and Li^+, these ions are also without appreciable effect on the electrode potential except when they are present in unusual concentrations.

Besides the above "ion errors," other factors may limit the precision and accuracy with which Na^+ activity can be measured in a given application. One source of error arises from electrode drift. For a representative bulb electrode, the drift measures less than 100 microvolts in any minute and less than 500 microvolts in an hour. In terms of equivalent Na^+ activity change, this amounts to less than 0.5 percent per minute and 1.3 percent per hour, respectively. Other limits to sensitivity and selectivity are amplifier sensitivity and noise, reference electrode noise, reproducibility of voltages when changing solutions, purity of reagents, the accuracy of preparing standards, stray electric fields, and temperature fluctuations of the system. Our observations have been confined chiefly to relatively gross measurements made with a standard Beckman model G pH meter. With this crude equipment we have been able to *detect* differences as small as 1 percent between standard NaCl solutions. With greater refinement of technique, we anticipate that one should be able to *measure* Na^+ activity to 0.1 percent with commercially available high-gain electrometers and without taking a prohibitive number of readings.

In biological applications, two other possible sources of error may exist. One is the possibility of an effect of protein on the glass. We have found no qualita-

tive indication of poisoning by constituents of serum, cerebrospinal fluid, or brain homogenate when electrodes are soaked in these fluids for many hours; the electrodes have yielded correct potentials in standard solutions immediately upon removal. The electrodes also show the expected potentials when known concentration changes of Na^+, H^+, K^+, or Ca^{++} are produced in the aforementioned fluids and when the unknown contribution to the ionic strength due to protein is disregarded [see Northrup and Kunitz (*13*) and Scatchard *et al.* (*14*) for data supporting this assumption]. When using these electrodes in intact biological systems, one must also be able to distinguish other sources of electrical potential difference between the electrodes such as electric potential fields of membrane origin or diffusion potentials which might result from extracellular ionic concentration gradients. Methods have been developed which are capable of accomplishing this distinction (*15*) both in principle and in simple cases which have been tested.

While our primary concern has been to maximize Na^+ specificity (the limits of which are still unknown), we have also discovered that certain compositions of the Na_2O-Al_2O_3-SiO_2 system are more sensitive to K^+ than to Na^+. Thus, in Figure 3*D*, such a composition region is seen in the shaded area below the 1 contour line. The most selective glass of this system for K^+ relative to Na^+ lies below the 0.3 contour and is about 6 times as sensitive to K^+ as to Na^+. It should be noted that, by using such a glass electrode in conjunction with the highly Na^+ selective $NAS_{11\text{-}18}$ electrode, it is possible to measure uniquely both the Na^+ and K^+ activities of an unknown mixture if one solves the two simultaneous electrode equations.

Conclusion

We conclude that a sodium aluminosilicate glass containing 11 moles percent of Na_2O, 18 moles percent of Al_2O_3, and 71 moles percent of SiO_2 offers electrodes of practical usefulness for selectively measuring the sodium ion activity as a continuous function of time in certain ionic mixtures, including extracellular biological fluids.

References and Notes

1. B. von Lengyel and E. Blum, *Trans. Faraday Soc.* 30, 461 (1934).
2. The initial part of this work was performed in the Anesthesia Laboratories of Harvard Medical School at the Massachusetts General Hospital and was aided by a grant from the National Foundation for Infantile Paralysis.
3. All but four glass compositions were made in our laboratory using a gas-oxygen furnace for 2 to 4 hours between 1300°C and 1650°C. (We thank William C. Wescott who made many glasses and Lewis E. Russell of the department of ceramics of Massachusetts Insti-

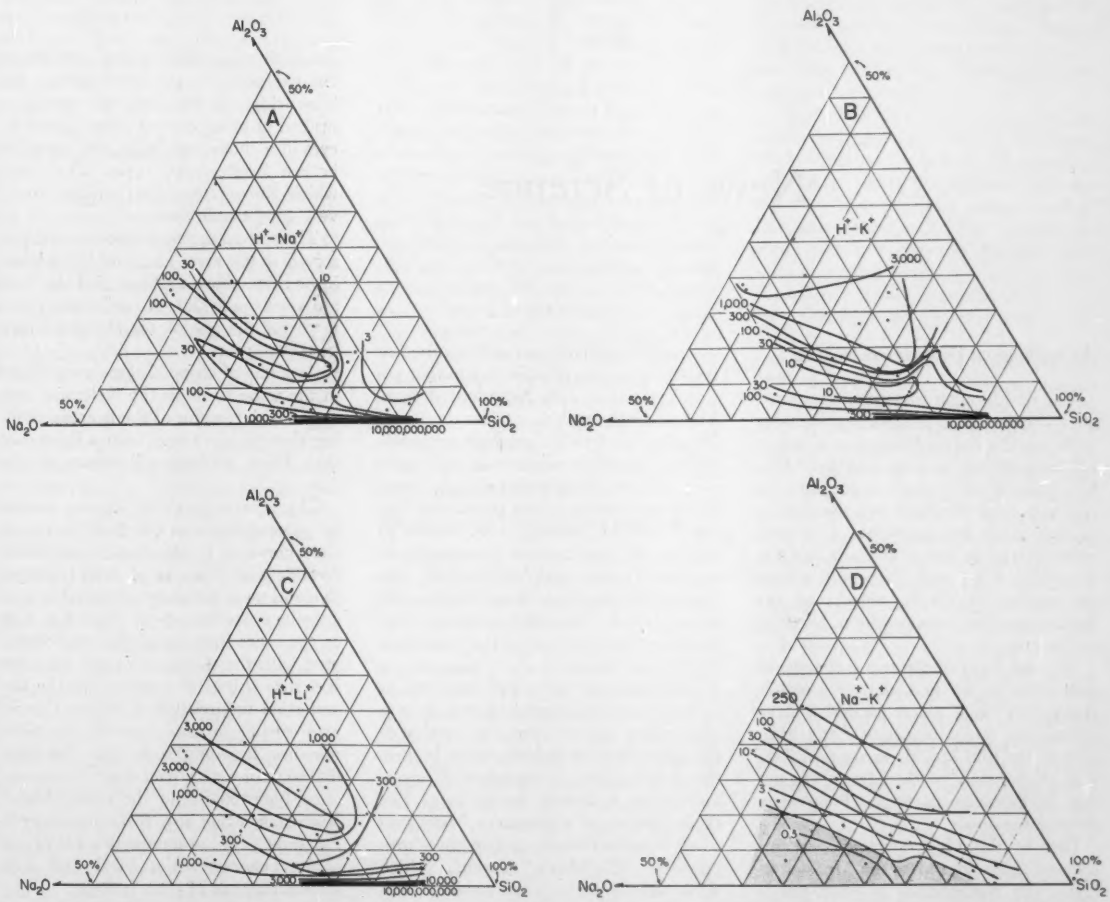

Fig. 3. Contours of isosensitivity in the high-silica corner of the Na_2O-Al_2O_3-SiO_2 composition field. Coordinate lines are given at 5 moles percent intervals. Points represent chemically analyzed glass compositions studied. The contour lines of isosensitivity are graphical interpolations from electrode potential data obtained at these composition points. The contour numbers indicate the ratio of the relative sensitivities for the specified ion pairs and are reciprocals of the k_{AB} values. Data in *A*, *B*, and *D* were obtained at *p*H 7.6; data in *C* were obtained at *p*H 6.6. In *D* note regular change in Na^+ to K^+ sensitivity and especially its reversal across the 1 contour line.

tute of Technology, who made two initial melts of Du glass.) Denver fire clay or alumina crucibles were used. SiO_2 was added as Pennsylvania Glass Sand, Na_2O as the carbonate, and Al_2O_3 as the hydroxide (both as Mallinckrodt analytical reagents). Two compositions (NAS_{10-10}, NAS_{11-18}) were made to our specifications by E. B. Shand of the Corning Glass Works. Glasses were analyzed for major constituents and trace impurities by the U.S. Testing Company. The final composition differs from that of the initial mixture in a complex manner but always has a significantly lower Na_2O and Al_2O_3 content. The losses generally take place along paths pointing toward the SiO_2 corner of the ternary diagram and are roughly proportional to the initial Na_2O or Al_2O_3 content. Data in terms of initial composition also yield systematic plots, a useful finding for surveying glasses. Haber-type bulb electrodes (3 to 10 mm in diameter) were made from small pieces of tubing blown in a gas-oxygen flame. A few small membrane electrodes (less than 300 μ in diameter) on lead glass stems were prepared by modifying the method of MacInnes and Dole. It should also be possible to prepare microelectrodes in the form of fine capillaries of sodium-sensitive glass sealed by fusing at the tip. Electrodes were filled with 0.1*M* NaCl and stored in the same solution at least 24 hours prior to study, although 0.1*M* HCl was also used without difference in results. A chlorided silver wire formed the internal electrode. Immediately prior to study, the stem of the electrode was rinsed with distilled water, dried and insulated by dipping in paraffin. The insulation proved satisfactory for several hours and could be renewed when necessary. The bulk of the measurements were made in solutions less concentrated than 0.1*M* with a Beckman model G *p*H meter and a Beckman KCl calomel fiber reference cell. Solutions were prepared directly from Baker analyzed reagents and analyzed spectrographically for impurities, which were found to be unimportant. Experiments were designed so that liquid junction potentials contributed no important error. (In Figs. 1 and 2, the liquid junction was held constant by keeping the concentration of the macrocomponent of the mixture unchanged; in Fig. 3, only the glass electrode was varied.) Single-ion activity coefficients for Na^+ and K^+ equal to the mean activity coefficients were assumed. The resistance of representative bulb electrodes lay between 10^9 and 10^{10} ohms. Most glasses respond rapidly to Na^+ change, coming to a stable value while being washed. No attempt has been made to measure the high-frequency noise (above 100 cy/sec) or to measure the response time to a rapid step in Na^+ concentration.

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11. The extreme abruptness of development of alkali cation sensitivity relative to H^+ with small additions of Al_2O_3 is likely to be of practical significance in minimizing the cation error of *p*H glass electrodes since this finding suggests that even minute traces of alumina are to be avoided in preparing such glass melts.
12. For Ca^{++} and Mg^{++}, these numbers are to be taken as indicative of order of magnitude only since equations for electrode potential in mixtures of ions of unequal valence have not yet been verified.
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News of Science

Archeological Discoveries in Iraq

The Smithsonian Institution sponsored an archeological expedition to Shanidar Valley in the Zagros Mountains of northern Iraq during the season 1956–57 that has resulted in several important discoveries, chief of which are the finding of two adult human skeletons of pre-modern type in Shanidar Cave and the discovery of an early Neolithic village site nearby. Ralph S. Solecki of the Smithsonian led the expedition, his third to the area.

The discovery of the two skeletons, as well as an earlier find, that of a child's skeleton in 1953, places Shanidar Cave among the more important Early Man sites in the Old World. In western Asia it is second only to the Mount Carmel site in Palestine in upper Pleistocene skeletal remains.

Both of the adult skeletons were recovered from the top of the Mousterian layer, the bottommost of four stratigraphic layers at Shanidar Cave. One of the skeletons was found at a depth of 14.5 feet below the surface, and the other at about 23 feet. In both, the bones were in an unfossilized or natural state.

The Mousterian layer is recognized as belonging to the Middle Paleolithic period associated with Neanderthal man. The skeletal remains appear to be of Neanderthal type on preliminary observation, and their position in the upper part of the Mousterian layer, above which was found a layer containing Upper Paleolithic artifacts very similar in type to its Aurignacian counterpart in western Europe, indicates a very late type of Neanderthal man. The bottom of the Upper Paleolithic layer has been dated by the carbon-14 test to be about 34,000 years old.

The shallower of the two skeletons, by virtue of its stratigraphic depth, is possibly about 45,000 years old. Although the bones in this skeleton were broken, the skeleton is fairly complete. It measures about 5 feet 3 inches long. The skull appears to represent a "conservative" Neanderthaloid, unlike the "progressives" of Mount Carmel, which show mixed features resembling both *Homo sapiens* as well as Neanderthals. In fact, the skull of Shanidar man more closely resembles that of the Neanderthal man of the La Chapelle-aux-Saints (France) find, which is a classic or conservative type. There is one very apparent exception to the resemblance. The brow ridge in the Shanidar specimen, instead of being carried across above the eyes in a continuous bulge, or "torus," is broken between the eyes. The teeth, which show rather heavy wear, are in very good condition.

The second skeleton is not so well preserved as the first. The skull has a heavy brow ridge above the eyes, and the teeth are worn quite flat. A conservative estimate for the age of the skeleton might be 60,000 years.

Artifacts of chipped stone were found in the same strata as the skeletons, associated with remains of fire hearths, showing that the cave had been a habitation site. These artifacts are Mousterian in type.

The nearest locus of ancient skeletal or paleoanthropological finds in significant numbers is Mount Carmel, where Neanderthal skeletons of both conservative and more humanly advanced or progressive types have been recovered. One of the more interesting problems associated with the discovery of the Shanidar skeletons is that it appears that the Neanderthal progressives of Mount Carmel were earlier in time than the Shanidar remains. It would seem that Neanderthal man of a very backward or conservative type existed in the mountains of Kurdistan, while only 600 miles away in Palestine a type of man with some *Homo sapiens* characteristics lived and died some thousands of years before.

The recent excavations bring the total of skeletal finds at Shanidar Cave to six, including three skeletons of Mousterian man or Neanderthaloids, two Neolithic burials, and one Islamic age skeleton.

There is promise of additional finds, since only a portion of the cave deposits has been examined.

The early Neolithic village site investigated by the expedition fits in the stratigraphic record of the long sequence in Shanidar Cave. The stone foundation remains that were uncovered indicate some kind of rude architecture. The site is one of the oldest thus far known in Mesopotamia, predating the village site of Jarmo, excavated in southern Kurdistan by the University of Chicago expeditions several years ago. It appears to equate with Karim Shahir, one of the early village sites identified in Iraq.

The Iraq expedition was supported by grants from the Smithsonian Institution, the American Philosophical Society, the National Science Foundation, the Wenner-Gren Foundation for Anthropological Research, and the William Bayard Cutting Traveling Fellowship of Columbia University. Two oil companies in the Near East, the Iraq Petroleum Company and the Arabian American Oil Company, cooperated in the expedition's work. As in the past two seasons, the Iraq Directorate of Antiquities gave its cooperation.

Deep-Sea Organisms

Live specimens of a sand flea and a sea worm were recently brought up from ocean depths of 13,200 and 16,200 feet, respectively, by a research group aboard the *Vema*, a vessel operated by Columbia University's Lamont Geological Observatory. Robert Menzies, director of biology and research associate in geology at Lamont, was chief scientist of the expedition.

Usually organisms brought to the surface from great depths are dead. The sand flea, really a shellfish that resembles a ⅛-inch lobster, survived a temperature change of from 34°F to 61°F without any apparent ill-effects. It was taken in the Congo Submarine Canyon off the coast of West Africa at latitude 5°S., longitude 8°E. The worm was taken in the Cape Basin off South Africa at latitude 28°S., longitude 8°E., and underwent the same temperature changes as the sand flea.

AEC Program to Aid Nuclear Technology in the Life Sciences

The Atomic Energy Commission has established another program to stimulate education and training in the application of nuclear technology to the life sciences. The commission has announced that it will make grants for the acquisition of specialized radiation equipment and teaching aids by accredited schools of agriculture, veterinary medicine, medicine and pharmacy, and public health, and by departments of biophysics and biology in colleges and universities.

Assistance will be provided for the purchase of radioisotopes and specialized equipment—including radiation detection, monitoring, and counting instruments—equipment for laboratory instruction in the analytical chemistry of radioactive materials of direct application in the life sciences, and equipment for laboratory instruction in health physics. Grants may not exceed $250,000 for any single institution. Further information about the new program may be obtained from the Director, Division of Biology and Medicine, U.S. Atomic Energy Commission, Washington 25, D.C.

Report on Research

The implications of basic research for the Nation's economy and defense are still not properly appreciated in this country, according to a report on *Basic Research–A National Resource* by Alan T. Waterman, director of the National Science Foundation. Waterman compares the financial support given applied research and development with that afforded basic research; he finds economic incentives sufficient to insure the future of the former, but not of the latter. He also emphasizes that basic research needs increased support from private industry, state government, foundations, and the general public; however, when other sources are not available, the Federal Government must assume responsibility for support. The report, which is written in nontechnical language, is on sale for 45 cents a copy at the Government Printing Office, Washington 25, D.C.

Rheumatic Fever Institute Merges with Worcester Foundation

The Rheumatic Fever Research Institute, Chicago, Ill., merged with the Worcester Foundation for Experimental Biology, Shrewsbury, Mass., on 1 October. The institute has turned over its personnel, research projects, assets, grants, and name to the Worcester Foundation and will move to Massachusetts in the fall of 1958, when a new laboratory is expected to be completed. Scientists making the changeover will include Eugene L. Hess, known for his studies of proteins of the lymphatic system, and Yutaka Kobayashi, an entomologist.

The Chicago Institute was incorporated in 1947 under the directorship of A. F. Coburn as an independent, nonprofit medical research institute affiliated with the Northwestern University Medical School. It employed about 25 people, including those working on basic research and physicians studying clinical aspects of rheumatic fever. Under the merger the clinical work has been discontinued, and basic biochemical studies have been emphasized.

Until the new laboratory is completed, adding approximately 25,000 square feet to the Worcester Foundation, a branch of the foundation will be maintained on the top floor of the Municipal Contagious Disease Hospital in Chicago.

NSF Fellowships

The National Science Foundation has announced that applications are now being accepted in four of its fellowship programs for advanced study and research in the natural sciences: a predoctoral fellowship program for which college seniors and graduate science students may apply; a postdoctoral fellowship program; a senior postdoctoral fellowship program for candidates who have held the science doctorate for a minimum of 5 years; and a science faculty fellowship program for college teachers of science who wish to improve their competence as teachers.

Approximately 1000 awards will be made to American citizens in March 1958. Under the broadened program, fellowships will be awarded in the mathematical, physical, medical, biological, engineering, and other sciences, including anthropology, psychology (other than clinical), geography, certain interdisciplinary fields, and areas of convergence between the natural and social sciences.

Stipends vary with the academic status of the fellow. First-year fellows, students entering graduate school for the first time or those who have had less than 1 year of graduate study, will receive annual stipends of $1600. Fellows who need one final academic year of training for the doctor's degree will receive annual stipends of $2000. Fellows between these groups will receive stipends at the rate of $1800 annually. The stipends for regular postdoctoral fellows will be $3800 per year. Dependency allowances will be made to all married fellows. Tuition and laboratory fees and limited travel allowances will also be provided.

Senior postdoctoral fellows and science faculty fellows are awarded stipends adjusted to match as closely as feasible the regular salaries of the award recipients up to a maximum of $10,000 per year. A travel allowance is also usually made available.

National Science Foundation fellows may attend any accredited nonprofit institution of higher education in the United States or a similar institution abroad. Applications for the 1958–59 National Science Foundation graduate and regular postdoctoral fellowship pro-

gram may be obtained from the Fellowship Office, National Academy of Sciences–National Research Council, 2101 Constitution Ave., NW, Washington 25, D.C. The closing dates for receipt of applications are *23 December 1957* for postdoctoral applicants, and *3 January 1958* for graduate students working towards advanced degrees in science.

Applications for the senior postdoctoral and the science faculty fellowships may be obtained from the Division of Scientific Personnel and Education, National Science Foundation, Washington 25, D.C. Completed material must be received not later than *13 January 1958*.

Teaching Films

A sound-track teaching film, "Respiratory Gases and the Determination of the Respiratory Quotient," may be purchased or rented from the Bureau of Audio-Visual Instruction, State University of Iowa. The reel, which was produced by the department of physiology, provides demonstrations of several instruments, including the Haldane gas analyzer, and shows a sample calculation that might be required of students. Two additional teaching films are being planned.

Protein Molecule That Contains Cadmium

A protein of low molecular weight that contains 2.2 percent cadmium has been isolated from the cortex of the horse kidney by Marvin Margoshes and Bert L. Vellee of the department of medicine at Harvard Medical School. The exact physiological function of the cadmium has not yet been determined. However, isolation of the cadmium-containing protein bears out an earlier hypothesis that cadmium, like zinc, could be part of protein molecules that occur naturally. The work was reported in a recent issue of the *Journal of the American Chemical Society*.

New Biology Quarterly

A new quarterly journal, *Perspectives in Biology and Medicine*, has been announced by the Division of Biological Sciences at the University of Chicago. The journal, which is dedicated to a multidisciplined approach to the problems of biology and medicine, will present new hypotheses and concepts as well as interpretive essays dealing with recent and current research.

Dwight J. Ingle and S. O. Waife are the editors for the publication. They will be assisted by an 11-member editorial board and by a 12-man advisory board that includes Sir Henry Dale of London, B. A. Houssay of Buenos Aires, and U. S. von Euler of Stockholm. Subscriptions for the journal ($6) are now being accepted by the University of Chicago Press, 5750 Ellis Ave., Chicago, Ill.

Graduate Education

The Carnegie Corporation of New York has announced that it will sponsor a 2-year, $100,000 study of graduate education in the United States. The project will be conducted by Bernard Berelson, who returned to the University of Chicago on 1 October as professor of the behavioral sciences. Since 1951, Berelson has been director of the Ford Foundation's behavioral sciences program.

The survey will be concerned with the objectives, standards, and functions of the graduate school in the American system of higher education. Berelson will make a broad review of the history of graduate education and its institutions in order to locate and interpret major trends and active issues.

Among the specific topics he will examine are the recruitment of students and placement of graduates; relations between graduate education and professional education, and between graduate education and undergraduate programs; the development of postdoctoral programs; and problems of financial support. The final report will discuss the important issues and problems facing graduate education, current policies and alternatives, and make recommendations about the formation of graduate school policies in the coming decades.

News Briefs

A 36-circuit submarine telephone cable system, probably the world's longest and deepest, has recently been completed. The two cables in the system cross the Pacific between Point Arena, Calif., and Hanauma Bay near Honolulu, Hawaii. The lines were laid by the American Telephone and Telegraph and the Hawaiian Telephone Company at a cost of $37 million. American and Canadian operators can now dial any number on the island of Oahu, and conversely, Honolulu operators can dial 6900 American and Canadian towns.

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A new twin-tailed comet has been discovered. It was first sighted by Howard S. Gates of the Mount Palomar Observatory.

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New York University plans a $1,750,000 expansion of its College of Dentistry. A ten-story building has been purchased that will complete the development of a Dental Center. The new quarters will at least double the area for teaching the clinical sciences in dentistry.

* * *

A survey of New York City's high school seniors was conducted recently in an effort to determine the percentage of students who were considering science as a career. The survey was carried out by Samuel Schenberg, Science Supervisor of the New York City Board of Education, and is reported in the 30 September issue of *Chemical and Engineering News*.

* * *

Fifteen scientists from five continents recently participated in a 5-day conference in Washington, D.C., to study the classification of atherosclerotic lesions. The meeting, which was called by the World Health Organization, was conducted by the Pan American Sanitary Bureau with collaboration of the National Heart Institute.

* * *

An educational TV series entitled *International Geophysical Year* has been arranged by National Broadcasting Company and the Educational Television and Radio Center. The 10-week program begins on 28 October. Six well-known scientists are participating: Joseph Kaplan, Roger R. Revelle, Laurence M. Gould, the Rev. J. Joseph Lynch, Lloyd V. Berkner, and Walter O. Roberts.

* * *

Exercises in commemoration of John Clayton, a botanist of the American colonial period, were held on 11 October in Williamsburg, Va., under the sponsorship of the College of William and Mary and the Garden Club of Virginia.

* * *

A safe, portable container for radioisotopes used to x-ray ship structures has been developed at the U.S. Naval Ordnance Laboratory. In addition to its primary purpose, the exposure fixture, which was built by John C. Friedrichs of the X-Ray Laboratory, also provides a means of temporary storage.

Soviet Scientific Literature

An article on the "Publication of Scientific Literature in USSR During 1957" appeared in a recent issue of *Current Science*, a journal that is published in India for the Current Science Association, Bangalore. The article said:

"The USSR Academy of Sciences will put out close to 1,500 titles and issue Journals [containing a total of] . . . 32,000 signatures in 1957. The range of subjects will cover all spheres of the humanitarian, natural and technical sciences.

"In the scientific and technical part of the programme of publications envisaged by the Academy, mention may be made

of books on mathematics, physics and chemistry, including works by the mathematicians A. M. Lyapunov and N. N. Luzin, Geophysicist P. P. Lazarev, Physicist Y. I. Frenkel, Organic Chemist A. N. Butlerov, and Radiochemist V. G. Khlopin.

"The computation mathematics series, recently organised by the Computation Centre of the Academy, will contain articles on methods of solving mathematical problems, estimates of errors of different methods and the solution of concrete mathematical problems.

"The biography of the great mathematician N. I. Lobachevsky, including 360 documents of archive materials unpublished previously, has been prepared by the Institute of History of Natural and Technical Sciences.

"Revised and supplemented editions of Academician A. F. Joffe's *Physics of Semi-Conductors* first issued in 1955, will be put out, as also L. I. Brekhovakikh's monograph of 'Waves in Layered Media.'

"To commemorate the Fiftieth Death Anniversary of I. D. Mendoleyev, the great Russian chemist, the Academy has collected articles from Soviet scientists [to issue] . . . as 'Classics of Science,' and also has arranged publication of a book entitled *The Periodic Law,* describing Mendoleyev's classical works on the subject.

"A volume of previously unpublished manuscripts of Charles Darwin and a monograph by Academician N. I. Vavilov on 'World Resources of Local and Selected Varieties of Cereals, Grains, Legumes and Flax and Their Use in Plant Breeding' will also be published.

"In addition, the publication of important books on the different branches of engineering, biochemistry, microbiology, soil sciences, zoology, physiology, botany, genetics and forestry is in the programme."

Scientists in the News

FARRINGTON DANIELS, chairman of the department of chemistry at the University of Wisconsin, has won the annual $1000 James Flack Norris Award of the American Chemical Society's Northeastern Section for "excellence in the teaching of chemistry." He will receive the prize at a meeting of the Northeastern Section on 15 Nov.

JOSHUA R. C. BROWN, associate professor of zoology at the University of Maryland, has joined the staff of AAAS for the academic year 1957–58 as assistant director of the Science Teaching Improvement Program. Brown will give four-fifths of his time to the AAAS and one-fifth to Maryland, where he will continue his research in cytology and direct the work of graduate students. During the summer he served as assistant director of the university's summer institute for science teachers that was sponsored by the National Science Foundation. Brown replaces I. E. WALLEN, who has joined the staff of the educational division of the Atomic Energy Commission.

I. MELVILLE STEIN, president of Leeds and Northrup Company, Philadelphia, Pa., has received an honorary degree of doctor of science from Rensselaer Polytechnic Institute.

HAROLD P. STEPHENSON, formerly professor of physics at Illinois Wesleyan University in Bloomington, has recently joined the staff of the Duke University College of Engineering as associate professor of mechanical engineering.

AKSEL A. BOTHNER-BY, a member of the chemistry faculty at Harvard University, has been appointed a staff fellow in fundamental research at the Mellon Institute, Pittsburgh, Pa.

ARTHUR A. FROST, a member of the Northwestern University chemistry faculty since 1936, has been named chairman of the chemistry department for the 1957–58 academic year. He succeeds ROBERT L. BURWELL, JR., who is retiring as chairman to devote more time to teaching and research.

MALCOLM C. McGREGOR, an officer of the Australian National Standards Laboratory, is at present in Washington, D.C., as a consultant to assist the National Bureau of Standards in setting up a new type of capacitance bridge that he recently developed in Australia in collaboration with A. M. THOMPSON. The bridge is of the induction ratio arm type, and its use makes measurement of capacitance to the order of 1 micropicofarad possible. Details have not yet been published. McGregor expects to remain in the United States for about 6 months. He will be working in the Section of Electricity and Electronics at NBS.

R. W. BROWN, former director of the George Washington Carver Foundation, has been appointed to the newly created position of dean of research at Tuskegee Institute. He will have general responsibility for the organized research programs of both the Carver Foundation and the institute's department of social science research.

CLARENCE T. MASON, former director of research at the Carver Foundation, has been appointed director of the foundation and chairman of the Tuskegee Division of Natural Sciences. The division has been organized under the College of Arts and Sciences to include the departments of chemistry, biology, physics, and mathematics.

CHARLES D. MARPLE, medical director of the American Heart Association since 1952, has been appointed medical director of the American Foundation for Allergic Diseases, New York. He will administer the research and scientific program of the foundation, as developed by its Scientific and Educational Council, and will be responsible for developing an educational program for both physicians and laymen concerned with the causes, treatment, and prevention of allergic diseases, and with related basic sciences.

CARROLL E. PALMER, research worker for the U.S. Public Health Service, has won the Weber-Parkes Prize of the Royal College of Physicians, London. He is to receive the award, a silver medal and $441 in cash, for his work in tuberculosis immunization with BCG.

D. J. STRUIK, professor of mathematics at Massachusetts Institute of Technology, has been nominated to an Extraordinary Professorship at the National University of Mexico, Mexico, D.F. He also has been elected an honorary member of the Mexican Mathematical Society.

HAROLD L. STEWART, chief of the Pathological Anatomy Branch, Clinical Center, National Institutes of Health, Washington, D.C., and chief of pathology for the National Cancer Institute, has received the Ward Burdick Award, which is given annually for outstanding service in the field of pathology. The presentation was made during the joint annual meeting of the American Society of Clinical Pathologists and the College of American Pathologists that took place recently in New Orleans, La.

WILLIAM F. MARLOW, formerly a radiochemist for the U.S. Army Engineers Research and Development Laboratories, Fort Belvoir, Va., has joined the radioactivity section of the National Bureau of Standards. He will investigate the chemical principles involved in the preparation of radioactivity standards; these are used for calibration of equipment for radiation measurement in scientific, medical, and industrial laboratories throughout the country.

MARY E. RAWLES has joined the staff of the department of embryology of the Carnegie Institution of Washington, Baltimore, Md., where she will not only continue her studies of development in birds and mammals, but will also assume new responsibilities as the curator of the Carnegie Embryological Collection.

Throughout her scientific career, Rawles has been closely associated with B. H. Willier, for the past 17 years in the department of biology at Johns Hopkins University.

RICHARD K. WINSLOW, for the past 3 years science editor of *Newsweek* magazine, has been named science editor of Doubleday & Company, Inc., book publishers.

JOSEPHINE M. MITCHELL, a research mathematician at the Westinghouse Research Laboratory, has been appointed associate professor of mathematics at the University of Pittsburgh. Also at Pittsburgh, ARNOLD H. BUSS, formerly chief psychologist for the Carter Memorial Hospital in Indianapolis, Ind., has been named associate professor in the department of psychology.

FRANS VERDOORN, managing editor of the Chronica Botanica Company and secretary of the International Biohistorical Commission of Waltham, Mass., has been appointed director of the new Biohistorical Institute of the University of Utrecht, Netherlands. This institute, now being set up in conjunction with Professor Lanjouw's Botanical Museum and Herbarium, will concern itself with the cultural, historical, and other humanistic and related aspects of the pure and applied life sciences, with some special reference to the plant sciences. It will be located in a building at 187 Nieuwe Gracht, bordering on the Utrecht Hortus Botanicus.

The publication program of the Chronica Botanica Company (with the exception of certain biohistorical publications to be issued in the Netherlands) is being taken over by the Ronald Press Company of New York City. Verdoorn will act as consulting editor, while JOHN A. BEHNKE, science editor and vice president of Ronald Press, will develop a "Chronica Botanica" division that will publish forthcoming volumes of *Chronica Botanica* and related serials.

JOHN C. CROWELL has been appointed chairman of the department of geology at the University of California, Los Angeles, to succeed WILLIAM C. PUTNAM, who will have completed a term of service of more than 7 years in the rotating departmental chairmanship.

Emeritus titles have been conferred on the following members of the science faculty at the University of Michigan: GEORGE M. BLEEKMAN, assistant professor emeritus of geodesy and surveying; CARL J. COE, assistant professor emeritus of mathematics; ROBERT C. COLE, professor emeritus of engineering drawing; LEE R. DICE, professor emeritus of zoology; KASIMIR FAJANS, professor emeritus of chemistry; HOLGER M. HANSEN, professor emeritus of engineering drawing; JAMES H. HODGES, associate professor emeritus of chemistry; REUBEN L. KAHN, professor emeritus of serology of syphilis and chief emeritus of the serology laboratory and of the serologic consultation service; JAMES A. NYSWANDER, associate professor emeritus of mathematics; MARTIN J. ORBECK, professor emeritus of engineering drawing; EARL C. O'ROKE, professor emeritus of forest zoology; EDWARD YOUNG, professor emeritus of geodesy and surveying.

GILBERT J. DALLDORF, director of the Division of Laboratories and Research, New York State Department of Health, has been appointed associate medical director of the National Foundation for Infantile Paralysis, effective 1 Jan. 1958. Long a leader in virus research, Dalldorf is known particularly as having been director, in 1947, of the project which first isolated the Coxsackie viruses, named for the New York State community in which they were first found. Some of these viruses cause symptoms similar to those of nonparalytic poliomyelitis; others have been found to be agents responsible for a number of cases of myocarditis in children.

C. JELLEFF CARR, formerly professor of pharmacology at Purdue University, has joined the Psychopharmacology Service Center of the National Institute of Mental Health as senior research pharmacologist.

ARTHUR B. LEWIS, chairman of the department of physics and astronomy at the University of Mississippi, has been named dean of the university's College of Liberal Arts.

Ramo-Wooldridge Corporation, Los Angeles, Calif., has announced the election of three new vice presidents: RUBEN F. METTLER, associate director of the company's Guided Missile Research Division; BURTON F. MILLER, director of the Communications Division; and MILTON E. MOHR, group director of the Control Systems and Boston Divisions.

Brigadier General JACQUARD H. ROTHSCHILD retired from the military service on 30 Sept. At the time of his retirement he was commanding general of the Army Chemical Corps Research and Development Command, with headquarters in Washington, D.C. Rothschild graduated from the United States Military Academy in 1930 and has served with the Army continuously since then. He also is a graduate of Massachusetts Institute of Technology with a master of science degree in chemical engineering practice. Rothschild will spend several months traveling abroad before settling in Boulder, Colo.

Recent Deaths

ERNST ARTSCHWAGER, senior pathologist of the Agricultural Research Service, U.S. Department of Agriculture, who had been conducting research at the New Mexico Agricultural Experimental Station for the past 25 years; 12 June.

BLASIUS BART, Chatham, N.J.; 74; electrochemist; held more than 30 patents in electrochemistry; founder and former head of the Bart Laboratories in Belleville, N.J.; 3 Oct.

LOUIS BONVICINO, Brooklyn, N.Y.; 68; retired neuropsychiatrist who taught neurology at several New York area medical schools; had been chief of neurological services at the former Italian Hospital and at the International Medical Center; 2 Oct.

JOHN W. BRANSON; president of New Mexico College of Agriculture and Mechanic Arts who had been successively head of the department of mathematics and dean of the college; 29 Sept.

JACOB W. FRANK, Drexel Hill, Pa.; 84; early leader in the x-ray field; one of the first to experiment with the use of intensifying screens in x-rays; first professor of radiology at Hahnemann Medical College and formerly head of its radiology department; 3 Oct.

JEKUTHIEL GINSBURG, New York, N.Y.; 68; professor of mathematics and director of the Institute of Mathematics at Yeshiva University; founder and editor of the university's journal, *Scripta Mathematica*; coauthor of *History of Mathematics in America* and author of *Number and Numerals*; 7 Oct.

ELIZABETH I. PARSONS, Atlanta, Ga.; 63; bacteriologist in charge, General Diagnostic Bacteriology Unit, Communicable Disease Center, U.S. Public Health Service, Chamblee, Ga.; former director of the State Hygienic Laboratory at Charleston, W.VA.; 6 Aug.

ROBERT L. PENDLETON, Baltimore, Md.; 67; Isaiah Bowman School of Geography, Johns Hopkins University; well known for his research on laterite and lateritic soils and for his many contributions both on land use in the tropics and in geography; 23 June.

EUGENE T. SCUDDER, East Orange, N.J.; chemical engineer for the Tung-Sol Electric Company, Bloomfield, N.J.; former Republican member of the State Assembly; partner in the Johnson and Scudder Chemical Laboratory, Hanover, N.J.; 3 Oct.

WILLIAM F. SUDRO, Neenah, Wis.; 72; retired dean of the School of Pharmacy at North Dakota State College; member of the North Dakota faculty for 48 years; 30 Sept.

Reports

Preserving Fluorescein Isocyanate for Simplified Preparation of Fluorescent Antibody

The extension of the fluorescent antibody technique (*1*) to staining microorganisms and viruses in clinical material (*2*) and the use of such labeled antibodies in a serological procedure (*3*) have made this technique of practical interest to many more laboratories than was previously the case. A major obstacle to the more widespread use of this valuable method has been the problem of preparing the fluorescein-labeled reagent. In this preparation, conversion of amino-fluorescein to fluorescein isocyanate is an important step. Because of the unstable nature of fluorescein isocyanate, the original recommendation was that it be prepared immediately before being mixed with the protein solution to be labeled (*1*). Inasmuch as conversion to the isocyanate requires the use of phosgene gas, which requires special care in handling because of its toxicity, the procedure is not well suited for intermittent performance by small laboratories, which may need to label different solutions at long intervals of time. For this reason, any method of stabilizing the isocyanate so that it can be kept on hand for long periods of time and shipped in a simple manner from one place to another is likely to extend greatly the potential use of fluorescein-labeled antibodies.

One approach to this problem has been to prepare acetone solutions of isocyanate, seal them in glass ampules, and keep them at low temperature. Under these conditions, no significant deterioration occurs for several months, at least (*4*). In this laboratory a different and simpler technique for stabilizing the isocyanate has been used. We have determined that acetone-dioxane solutions of fluorescein isocyanate can be dried onto filter paper or the like, and that the dried reagent stored in a desiccator at room temperature will remain active for at least 7 months (the longest period tested so far).

In order to investigate this method, we used aliquots from an anti-*Toxoplasma gondii* globulin solution whose capacity to stain the homologous species after being labeled with fluorescein had already been established (*5*). In assessing the quality of the labeling which was obtained with the dried isocyanate, homologous organisms were exposed to dilutions of the various labeled aliquots, and the brightness of fluorescence of the organisms was compared visually. The results of several exploratory experiments have led us to adopt the following procedures for preparing and using dried isocyanate.

Fluorescein isocyanate is prepared in the usual manner (*1*) and is dissolved in a quantity of acetone-dioxane (2/1) to yield a solution with the equivalent of 20 mg of amine per milliliter of solution. One milliliter of the solution is delivered into a small flat dish, and a piece of thick, chromatographic paper, 20 mm square, is used to soak up the solution in a uniform manner. Before use, the chromatographic paper is washed in distilled water and then in acetone in order to remove impurities that may cause the isocyanate to deteriorate. The acetone and dioxane we use to dissolve the isocyanate are both specially dried, the acetone by being kept over $CaSO_4$, the dioxane, by having metallic sodium added to it and then by distilling off the water-free solvent. The paper containing the isocyanate is dried in front of a fan for about 1 minute and is then put into a loosely covered glass dish, protected from light. The dish is kept in a desiccator over $CaSO_4$.

Originally, in order to use the dried paper, we prepared a buffered reaction mixture containing acetone and dioxane as well as the protein solution to be labeled. Subsequently, as a result of comparative experiments, it was found that dioxane in final concentration of up to 40 percent in the reaction mixture did not significantly change the staining capacity of the resulting labeled antibody solutions from that obtained in the absence of dioxane. When the concentration of dioxane was increased to 80 percent, a significant degree of protein denaturation occurred, resulting in a distinct lowering of staining capacity. As a result of these observations, we now use a reaction mixture that consists only of the protein solution in saline and 0.5*M* carbonate buffer at *p*H 9. The volume of buffer used is 10 percent of the volume of the protein solution to be labeled. The latter is brought to a concentration of 1 g/100 g by means of a mixture of buffer and saline (*6*).

The actual labeling process is very simple. The required amount of isocyanate is computed in terms of amine on the basis of 0.05 mg of amine per milligram of protein to be labeled. With the volume and size relationships we use, a strip of paper 1.0 by 20 mm contains 1 mg of amine equivalent, making it simple to estimate the size of the strip needed. A piece of paper of the proper size is added to the protein solution, prepared as described above, and maintained in an ice bath. After vigorous shaking of the mixture to make sure that the paper is thoroughly wetted down, the mixture is left overnight on a shaker in the cold and is then removed and dialyzed in the usual manner to remove the unreacted fluorescein derivatives (*1*).

Comparisons of the staining ability of conjugates prepared from dried, stored isocyanate and from freshly made isocyanate dissolved in acetone-dioxane have shown that the two types of conjugates are entirely comparable. We have no information on the fluorescein-protein ratios which result when the two methods are used, but, on a practical basis, the dried isocyanate has yielded conjugates that are as satisfactory as are those prepared in the conventional manner.

One unexpected advantage of this method has been the fact that no visible denaturation of protein occurs with it, whereas there is considerable denaturation when the isocyanate is used in the conventional manner. This observation led us to attempt to react the same antibody solution with fluorescein more than once in order to increase the staining power of the solution. The basis for trying this was the fact that it has been estimated that only 3 to 6 percent of the theoretically possible reactive sites of the protein molecules actually combine with fluorescein isocyanate in the usual labeling procedure (*7*). Previous attempts on our part to react the same antibody solutions more than once with freshly prepared solutions of isocyanate had resulted in great losses of protein by denaturation. However, by using the dried isocyanate it has been possible to double, approximately, the effective staining capacity of a solution by reacting it two or three times with the fluorescein. This is a distinct advantage when one is working with weak antisera or with small quantities of serum, which can thus be made to go farther.

All technical papers and comments on them are published in this section. Manuscripts should be typed double-spaced and be submitted in duplicate. In length, they should be limited to the equivalent of 1200 words; this includes the space occupied by illustrative or tabular material, references and notes, and the author(s)' name(s) and affiliation(s). Illustrative material should be limited to one table or one figure. All explanatory notes, including acknowledgments and authorization for publication, and literature references are to be numbered consecutively, keyed into the text proper, and placed at the end of the article under the heading "References and Notes." For fuller details see "Suggestions to Contributors" in Science 125, 16 (4 Jan. 1957).

The method used for relabeling is essentially a repetition of the original process. After the unreacted fluorescein derivatives have been dialyzed away, the labeled protein is simply shaken overnight again with the proper amount of dried isocyanate. Since the protein solution is already in approximately 1 gram percent concentration, no more saline is added. However, buffer is again added (10 percent of the original volume of the globulin).

In our opinion, the main advantages to be obtained from the use of dried isocyanate in the manner described above are (i) that the isocyanate can be prepared centrally in either commercial or noncommercial laboratories and can then be sent out to smaller research or diagnostic laboratories for actual use, and (ii) that an antiserum can be made to stain more intensely by relabeling, without danger of loss of protein content as a result of denaturation.

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31 July 1957

Mortality of Aquatic Insects and Fishes Caused by Use of Latex Tubing in Experimental Apparatus

A commonly used brand of latex rubber tubing was employed in the construction of apparatus for experiments on the dissolved oxygen requirements of certain aquatic insects under varying conditions of flow. A unit of the apparatus consisted of a glass tube through which water was continually recirculated by means of a small centrifugal pump. About 10 ft of ½-in. latex tubing provided the connections between the tube, a 5-gal bottle in which the dissolved gas content of the water was adjusted, and the pump. The test animals were held in the tube in a capsule of stainless-steel screen. The total volume of water in use at any one time was about 20 lit. During any one experiment there was no exchange of the water. Test water temperatures were about 20°C.

Table 1. Mortality associated with latex tubing in standing water tests.

Test No.	Animal	No.	Test conditions	Animals dead in		
				24 hr	48 hr	72 hr
1a	*A. pacifica*	10	Latex tubing		3	7
1b	*A. pacifica*	10	(control)		0	0
2a	*A. californica*	10	Latex tubing		5	6
2b	*A. californica*	10	(control)		0	0
3a	*L. reticulatus*	10	Latex tubing	0	0	5
3b	*L. reticulatus*	10	(control)	0	0	0
4a	*O. tshawytscha*	10	Latex tubing	10		
4b	*O. tshawytscha*	10	(control)	0		
5a	*O. tshawytscha*	10	Latex tubing	10		
5b	*O. tshawytscha*	10	(control)	0		
6	*A. californica*	10	Plastic tubing		0	0

In numerous trials it proved to be impossible, with the use of this apparatus, to keep more than a small percentage of the nymphs of *Acroneuria pacifica* and *Acroneuria californica* (Plecoptera) alive and in good condition, even under "control" conditions, for periods of several days. Usually, within 24 hours, some mortality occurred, and all or most of the surviving nymphs were in sluggish condition. Generally, in 2 or 3 days, about half of the nymphs were dead or moribund.

Subsequent testing of individual parts of the apparatus for harmful effects on the nymphs indicated that only the latex tubing could be responsible for the trouble. Confirmatory tests were conducted, in 1-gal glass jars, in which the two species of *Acroneuria*, fingerling king salmon (*Oncorhynchus tshawytscha*), and immature guppies (*Lebistes reticulatus*) were used. In these experiments a piece of latex tubing several feet long was coiled in the test jars filled with water. The animals were then introduced into the test water, which was kept well aerated and in continuous circulation by rising air bubbles. Appropriate controls were used. As Table 1 shows, no losses occurred among the control animals, but in all cases there was considerable mortality among the test animals, of all species, in the jars that contained the tubing. A piece of plastic tubing was used in a similar jar test. No deaths occurred, and the stonefly nymphs used appeared to be normally active after 3 days.

When about 1500 ml of water per minute flowed continuously and without recirculation or reuse through 10 ft of the latex tubing and into a glass tube containing stonefly nymphs, no difficulty was experienced in keeping the animals alive and in good condition for several days.

As a result of these experiments, the original apparatus was reconstructed and the plastic tubing, which had been found to be apparently harmless, was used; in the course of tests performed thereafter, with this apparatus, no unexpected mortality of stonefly nymphs occurred.

Although widely used and apparently entirely suitable for most experimental purposes, latex rubber tubing evidently should be used with caution in experiments involving the recirculation of water in closed systems where there is no continuous exchange of water and where species of animals sensitive to the constituents of the tubing are utilized. Even though mortality might not result from such use of the tubing, the results of sensitive physiological tests might be markedly influenced.

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8 July 1957

Synthesis of "On-Off" and "Off" Responses in a Visual-Neural System

The most distinctive feature of the discharge of impulses in the vertebrate optic nerve in response to a light stimulus is the marked activity elicited by changes in the level of illumination. The early records of Adrian and Matthews from the whole optic nerve (*1*) demonstrate a strong burst of activity when the light is turned on, a continuing discharge at a lower rate as long as the light remains on, and, upon the cessation of light, a renewed burst which gradually subsides.

Hartline (*2*) has shown that this composite response results from individual fibers whose activity differs markedly: some fibers discharge regularly as long as the light shines; others discharge only briefly when the light is turned on and again when it is turned off, with no activity during steady illumination; still others respond only when the light is turned off. These complex responses, observed in third-order neurones, have been ascribed by Hartline (*2*) and Granit (*3*)

to the excitatory and inhibitory interactions of retinal structures interposed between these neurones and the photoreceptors rather than to special properties of the photoreceptors themselves.

The reasons for this interpretation are many. One reason derives from the nature of these "transient" responses. Hartline (*4*) found that, in the eye of the frog, an "off" response elicited in a single fiber by illuminating one group of receptors may be suppressed by illuminating another group of receptors in the same receptive field, and Barlow (*5*) has obtained a similar suppression using stimuli outside the receptive field. Also, Kuffler (*6*) has shown that, in the cat, these diverse response "types" are labile and that, depending on the locus of illumination and the level of background illumination, a particular fiber may exhibit a variety of responses. Furthermore, the fibers arising directly from the ommatidia in the lateral eye of the invertebrate, *Limulus,* do not exhibit the diversity of response found in the vertebrate nerve. Although "off" responses have been found in the *Limulus* optic ganglion (Wilska and Hartline, 7), the typical response of *Limulus* optic nerve fibers to stimuli of long duration is a sustained discharge while the light is on and an immediate cessation of impulses when the light is turned off (Fig. 1*A*).

The relatively simple discharge pattern typically observed in fibers of the optic nerve of *Limulus* may be greatly modified by various means. First, a pronounced afterdischarge may be obtained by proper control of exposure time, intensity of the stimulus, and state of adaptation. Second, the frequency of the discharge of impulses may be decreased by illuminating neighboring ommatidia; this inhibition seems to be mediated by a plexus of lateral interconnections immediately behind the ommatidia (Hartline, Wagner and Ratliff, and Hartline and Ratliff, *8*).

By combining these various influences on the discharge of impulses, "on-off" and "off" responses have been "synthesized" in individual fibers of the *Limulus* optic nerve (*9*). Examples are shown in Fig. 1*B*. These responses possess the properties of the analogous responses in the vertebrate eye. The "on-off" responses are characterized by a burst of activity when the light is turned on, no further activity as the light stays on, and a final burst of activity after the light is turned off. The pure "off" responses also have the properties of the vertebrate response: no discharge appears until after the light goes off, and the discharge may be inhibited by reillumination. Both types of response have been obtained over a considerable range of stimulus durations.

A very delicate balance of excitatory and inhibitory influences is required to obtain these "on-off" and "off" responses in the optic nerve fibers of *Limulus*. The responses are not obtained under ordinary conditions of stimulation and have never been obtained when only one ommatidium is stimulated. From what we know of the properties of the inhibitory effect and of the temporal characteristics of the afterdischarge, we view the "on-off" response as occurring in the following manner: the onset of light stimulates several ommatidia, one of which gives rise to the fiber whose activity is being recorded. A few impulses are discharged in this fiber before the inhibitory influences from the neighboring elements completely suppress its activity. This suppression continues until the light is turned off. If the duration of the stimulus and the relative states of adaptation of the various receptors are adjusted so as to enhance the afterdischarge of the inhibited fiber and to minimize the afterdischarge of the neighboring elements, an "off" response is obtained. To obtain a pure "off" response the latency of excitation of the element whose activity is being recorded must be longer than the latency of the inhibition exerted upon it. This can be achieved by adjusting the angle of incidence of the light so that the element whose activity is being recorded is stimulated less effectively than are the neighboring elements which inhibit it.

The consequences of these experiments are twofold. (i) They lend support to the view that "on-off" and "off" responses are the result of the complex interplay of excitatory and inhibitory influences by showing that the experimental manipulation of these influences can, indeed, yield such transient responses; and (ii) they show the feasibility of using the *Limulus* preparation in the further study of these transient responses. This preparation offers distinct experimental advantages over the vertebrate preparation because the excitation and inhibition of individual receptor units may be easily and independently controlled and measured.

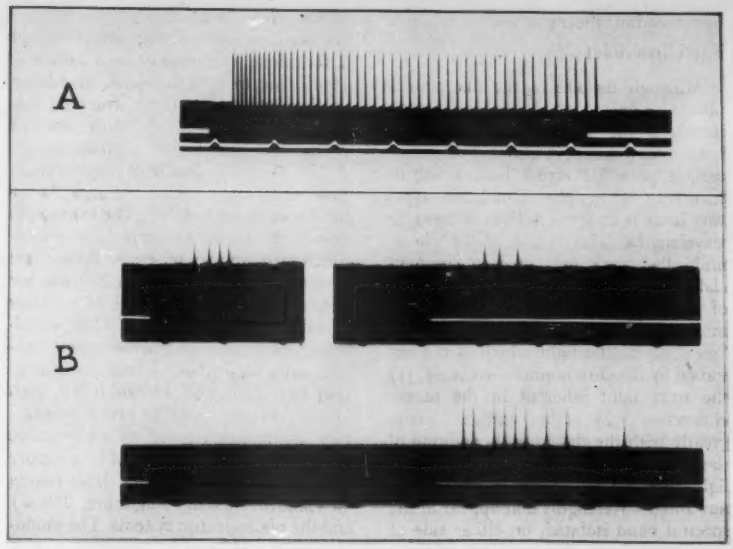

Fig. 1. Oscillograms of diverse "types" of impulse discharge patterns in single fibers of *Limulus* optic nerve. *A*, Typical sustained discharge in response to steady illumination. *B*, Upper record; a synthetic "on-off" response (approximately 1 sec was cut from the middle of this record). Lower record; a synthetic "off" response. Time is marked in 1/5-sec periods. Signal of exposure of eye to light blackens the white line above the time marker. Fibers whose activity is shown in the two *B* records gave a sustained discharge like that shown in *A* when the ommatidia from which they arose were illuminated alone.

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Spectrophotometry in the Far Ultraviolet

Although the use of the photomultiplier as a detecting device has greatly increased the resolving power of the spectrophotometer, it has also magnified certain potential errors because of its sensitivity (*1*). Photomultiplier types vary in their response to light of different wavelengths. The R.C.A. 1P28 photomultiplier, commonly used in commercial instruments, has a spectral response of between 2000 and 7000 A, with a maximum at 3500 A. Consequently, it "sees" all of the light which is not absorbed by the chromophore—namely, (i) the stray light inherent in the monochromator (*2*) (the amount varies greatly with the design and condition of the instrument used and the nature of the light source); (ii) those extraneous or unwanted wavelengths that appear in the spectral band isolated, on either side of the central "monochromatic" wavelength measured (the amount varies with the width of the slit); (iii) any fluorescent light emitted by the chromophore; and (iv) the fluorescent light emitted by fused silica cells.

Since Beer's law is valid only when monochromatic light is used, spectrophotometric measurements become increasingly subject to error with decreasing wavelengths for the following reasons. In the far ultraviolet, not only does the angle of dispersion of the prism of the monochromator increase rapidly but also the brilliance of the usual light source and the sensitivity of the photomultiplier decline simultaneously (manifestations caused largely by their fused silica envelopes) with the result that the slit must be opened more rapidly than theory indicates to balance the photoelectric bridge circuit. Consequently, with decreasing wavelengths, the ratio of stray light to monochromatic light increases rapidly, and the spectral band isolated is no longer effectively monochromatic.

Attempts (*3*) have been made to correct for stray light in this region by measuring the unabsorbed light emerging from concentrated solutions from which all the monochromatic light presumably had been selectively absorbed by the chromophore. Such corrections are themselves subject not only to the errors which are inherent in measurements of optical density in concentrated solutions but also to those arising from the fact that the incident monochromatic light is never completely absorbed.

The ideal solution to the problem would be the complete elimination of the stray light inherent in the monochromator as well as that caused by excessively large slit widths. Since the far ultraviolet is a spectral region in which many biochemically important compounds show characteristic absorption, it seemed worth while to develop a technique for the accurate study of this property. Such a technique might serve as a means of identifying these compounds, give information concerning their structure, and provide a tool for following the enzymic reactions in which they participate.

The technical details of a spectrophotometer for use between 195 and 230 mμ have been described (*4*). The instrument was designed to minimize the above-mentioned sources of error. Stray light of wavelengths longer than 280 mμ has been eliminated by the use of a "solar blind" photomultiplier (R.C.A. developmental type C7180) whose photocathode has a high photoelectric work function (*5*). Also, the slit width has been kept sufficiently small to give a satisfactory approximation of monochromatic light. This has been achieved by a proper balance between a brilliant light source (a Hanovia mercury-xenon arc, 250 w) and the photoelectric systems. The monochromator used was a Leiss single monochromator (*6*). Double monochromation in this system would serve only to reduce the optical efficiency of the instrument.

For work in the far ultraviolet, especially designed crystal quartz cells (*7*) were used for two reasons. First, the transmission of light in the far ultraviolet was demonstrated to be significantly greater with crystal quartz cells than with fused silica cells of the best available quality. With the solar blind photomultiplier and mercury-xenon arc, it was found that crystal quartz cells transmitted, at 195 mμ, 22 percent more energy than did fused silica cells; at 210 mμ, 4 percent more; at 220 mμ, 2 percent more; at 240 mμ, 6 percent more; and at 260 mμ, 1 percent more. Second, all of the many fused silica cells tested, and other samples of highly purified silica as well, showed a characteristic fluorescence which was not found in crystal quartz cells. The increased absorption observed at 240 mμ is caused by the excitation of fluorescence in silica, the maximum point of excitation being found at 244 mμ. The emission of this energy is said to be in the violet (*8*). This fluorescence will introduce an error into absorption spectra taken in fused silica cells when a photomultiplier employing either an S-5 or an S-13 surface is used.

Conformity with Beer's law was demonstrated when the optical densities of solutions of adenylic acid, observed at 210 mμ, were plotted as a function of concentration. Many absorption spectra of biochemically important compounds, including the nucleotides and the aromatic amino acids, have been taken; some reveal fine structure previously unobserved in this region (*9*). It is anticipated that the photoelectric technique described will eliminate the difficulties currently being found in following the course of enzymic reactions by observing difference spectra in the far ultraviolet in solutions of high optical density (*10*).

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1 July 1957

Cultivation of Adult Mouse Mammary Gland in Hormone-Enriched Synthetic Medium

As a part of our laboratory research program that is concerned with the factors responsible for the induction, maintenance, and neoplastic transformation of hyperplastic nodules in the mammary gland of mice of the C3H/He CRGL strain, we have been attempting the cultivation *in vitro* of tissues from various growth stages of the adult gland, normal and abnormal. Adult mouse mammary epithelium generally has been difficult to grow *in vitro* (*1*); however, Lasfargues (*2*) has recently obtained successful growth in tissue culture. Moreover, Hardy (*3*) observed some mammary duct growth but no alveolar development in organ cultures of ventral body wall from embryonic mice. This report describes the successful maintenance *in vitro* of adult mammary gland in synthetic medium with added purified hormones.

The Chen adaptation (*4*) to liquid medium of the organ culture method of Fell (*5*) was employed, and the synthetic culture medium "199" (*6*) was used. The cultures were incubated at 37°C, generally for 5 days, with the *p*H of the medium remaining at about 8.4. The hormones used were estrone, progesterone, cortisol, growth hormone, and

mammotropic hormone. The crystalline steroid hormones were dissolved in 100-percent ethanol, and a quantity of this solution was added to medium 199 to give the desired hormone concentration in the final medium and a 0.5-percent ethanol concentration. The same amount of ethanol was added to all other cultures. Progesterone and cortisol remained soluble in medium 199, whereas the concentrations given for estrone represent the amount in solution plus that in fine suspension. The purified protein hormones were added directly to medium 199 and sterilized by passage through a bacterial filter. A certain amount of the proteins did not completely dissolve and did not pass through the filter; thus, the actual concentrations were less than those given.

Mice of the C3H/He CRGL strain, at about the 14th day of pregnancy, provided prelactating mammary tissue with advanced lobuloalveolar development and marked secretory activity. The secretion in the alveolar lumina is often vacuolated, and the cells generally contain large lipid vacuoles. Tissue samples, usually slightly less than 1 mm in diameter, were taken from a single area of one gland and distributed among the various culture media. A sample from the same area was fixed and sectioned to determine the initial histologic state of the gland. At the end of the culture period, the explants were fixed in Bouin's fluid, serially sectioned, and stained with a modified Masson's stain.

In the medium-199 control cultures (Fig. 1*A*), the alveoli and small terminal ducts showed extensive degeneration, and the parenchymal cells were mainly dead or dying. In contrast, the larger ducts retained their organization and consisted of viable cells.

The 199 medium was enriched with a combination of estrone, progesterone, cortisol, growth hormone, and mammotropic hormone (effective *in vivo*) (see 7) in two concentrations. In the "high" concentration, containing 0.2, 2.0, 8.0, 140, and 140 μg/ml, respectively, of the hormones, the explants retained their original appearance in all respects (Fig. 1*B*), including prominent secretory activity, and in several cases appeared to be stimulated beyond their original state. During the culture period, some alveoli became white and opaque, owing to the accumulation of secretory products. After the standard 5-day culture period, some explants were transferred to fresh "high" medium for another 5 days. In general, they maintained their active secretory condition, with only slight evidence of degeneration. In the "low" concentration, wherein the amounts of hormones were 0.02, 2.0, 2.0, 20, and 20 μg/ml, respectively, the alveoli and terminal ducts also maintained their organization. However, the epithelial cells, although viable, were not actively secretory. The adipose and fibrous connective tissues associated with the glandular parenchyma did not appear to respond to the addition of hormones and survived equally well in the presence and in the absence of the several hormonal combinations.

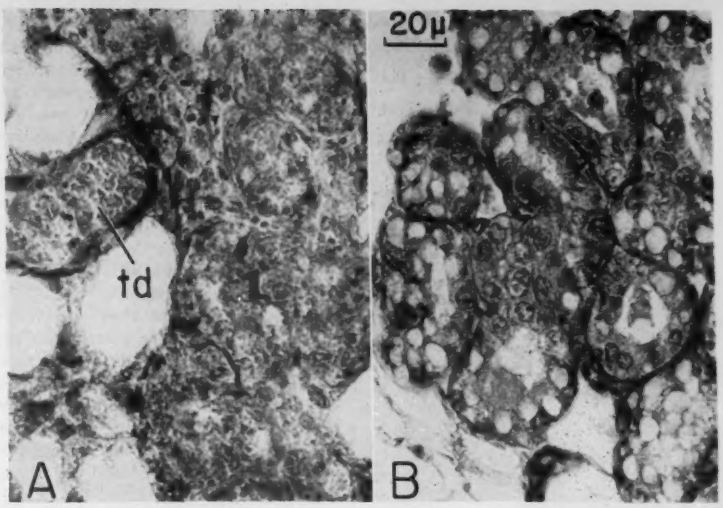

Fig. 1. (*A*) Section of explant from prelactating mammary gland after 5 days in control 199 medium, showing degenerate alveoli and terminal duct (*td*). (*B*) Explant from same gland in medium containing estrone, progesterone, cortisol, growth hormone, and mammotropic hormone in "high" concentration. Note active secretory appearance.

Experiments were then conducted to determine which of the five hormones used were essential for maintenance. The concentration of each hormone was the same as in the original "high" combination. Using media enriched with estrone and progesterone and with cortisol, growth hormone, and mammotropic hormone, it was found that all the activity was in the latter group. Each hormone of this group was then used individually. The results showed that neither cortisol nor growth hormone nor mammotropic hormone alone maintained the tissue. In the final experiment, cortisol and growth hormone, cortisol and mammotropic hormone, and growth hormone and mammotropic hormone media were tested. Of these, only the cortisol and mammotropic hormone combination was effective and showed full activity.

Hyperplastic alveolar nodules characteristic of the mammary gland of C3H/He CRGL mice were also cultured. These nodules are similar to prelactating lobules in organization and histologic appearance (*8*) and are considered to be precancerous lesions (*9*). Their reactions in all culture media employed were essentially similar to those of normal prelactating tissue; however, they seemed to be more responsive to the effective hormones. With explants from normal inactive gland, in which alveoli are relatively infrequent and are not organized into lobules, no successful cultures have been obtained to date. Only the larger ducts were maintained.

These initial results indicate that alveoli and terminal ducts are dependent on certain hormones for survival *in vitro*, whereas larger ducts survive in the absence of hormones. This is in accord with the fact that in hypophysectomized-adrenalectomized-ovariectomized female mice of the C3H/He CRGL strain, the alveoli degenerate, whereas the larger ducts remain (*10*). In our experiments, the hormone environment of the explanted tissue was almost wholly defined; the only questions concern the purity of the hormones used and the substances in the explants themselves. With these limitations in mind, it may be said that the hormonal combination of cortisol and mammotropin, acting directly on the explants, maintains and stimulates the secretory activity of prelactating and hyperplastic mammary lobules. Other steroids and proteins may be capable of producing these effects; experiments to test the specificity of the phenomena observed and to analyze further the hormonal control of mammary growth and function *in vitro* are now in progress (*11*).

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7 August 1957

Controlling Growth of Test Bacteria for Antibiotic Assays through Anaerobiosis

Sarcina lutea and *Micrococcus pyogenes* are standard Food and Drug Administration test organisms used in assay methods for antibiotics, including penicillin, aureomycin, and chloromycetin. Both bacterial species, if not obligate aerobes, display strong aerobic characteristics.

The inability of these antibiotic-sensitive bacteria to grow well in an oxygen-deficient environment prompted a study of the effects of strict anaerobiosis on (i) growth retardation when strains of these bacteria were imbedded in thin layers of agar, (ii) survival, under this condition, during storage at warm temperatures, and (iii) retention of sensitivity to antibiotics following resumption of growth.

Anaerobiosis was induced either by removal of air from the environment through high vacuum or by saturating the environment with nitrogen. Three milliliters of melted, sterile nutrient agar, seeded with a test organism, were layered into a disposable, plastic petri dish (60 mm in diameter). After solidification of the agar, the seeded plate was inserted into an aluminum-polyethylene pouch with low oxygen-transmission characteristics (*1*). Evacuation of the pouch to 29.0 in. (76 cm) of vacuum and automatic heat-sealing of the open lip was carried out with a high-speed, Flex-Vac controlled-atmospheric packaging machine (*2*). Other pouches were evacuated similarly and then gassed with nitrogen and sealed by heat. All sealed pouches (Fig. 1) were held 1 day at approximately 20°C during transit to the analytical laboratory, and then were stored at 34°C for a period of days. At specific intervals, 1, 3 and 13 days, some pouches were removed for examination of bacterial survival and of sensitivity to antibiotics.

The pouches were torn open to permit re-entry of oxygen. Then paper disks saturated with standard penicillin solutions of various concentrations were applied to the seeded nutrient agar surfaces; the plates were then incubated at 33°C for 6 hours or more to develop zoning.

The results are partly presented in Table 1. Strict anaerobiosis induced by automatic vacuum packing of aluminum-polyethylene pouches completely prevented growth of these bacteria at exposure temperatures of 20°C and 34°C. *Sarcina lutea* and *Micrococcus pyogenes* (*3*), under these conditions, survived for at least 12 days at 34°C, and removal of anaerobiosis by tearing open the pouch reinitiated growth in the agar with unimpaired sensitivity to penicillin. Generally, however, growth of bacteria after they had been kept dormant in the warm, airless environment was not as dense or as rapid as in the case of those grown on control plates (*4*), but with only a few exceptions, this did not seriously impair disk assay analysis. A few plates, three in this lot of 53 that were tested, failed to show growth after incubation for reasons not readily apparent.

Fig. 1. Aluminum-polyethylene pouch with seeded agar plate under 29-in. (76 cm) vacuum. The concavity of plate is an indicator of vacuum level.

The application of nitrogen to induce anaerobiosis produced results comparable to those obtained with high vacuum. Growth of bacteria held under nitrogen pack after 12 days' storage at 34°C was not as dense and rapid as that on control plates (*4*) that had been kept in cold storage under atmospheric conditions, but no significant loss of sensitivity against penicillin was observed. Carbon dioxide has not yet been tested, but in a well buffered medium, it conceivably would act in the same manner as nitrogen.

It is interesting that *Sarcina lutea* and *Micrococcus pyogenes* in most, but not all, instances survived and also retained sensitivity to penicillin when exposed in the absence of oxygen to long and extremely warm-temperature storage. More research in this area may show an application for these results. If growth control can be standardized with anaerobiosis by using an inexpensive, lightweight, gas-impervious package, a simple field test for the detection of antibiotics in milk and other biological materials might possibly ensue. An urgent need exists for a simple field test that would indicate effectively when milk has become adulterated with antibiotics at the farm. Such adulteration occurs after therapy of mastitis-afflicted dairy cattle with antibiotic infusions of the udder (*5*).

Perhaps, with proper selection of test organisms, a pocket disk or cup assay test for on-the-spot screening of antibiotics from natural sources might be designed. Furthermore, continued study with high-speed, vacuum and gas packaging of bac-

Table 1. Effect of anaerobiosis on growth of antibiotic-sensitive bacteria and on their retention of sensitivity to penicillin. Control plates were seeded and kept under atmospheric conditions for 13 days at 5°C. Vacuum plates were seeded and kept under vacuum for 1 day at 20°C and then 12 days at 34°C. Nitrogen plates were seeded and kept under a nitrogen atmosphere for 1 day at 20°C and then 12 days at 34°C. Measurements of zone diameter and observations of growth were made after 6 to 10 hours' incubation at 33°C.

Penicillin standard* (unit/ml of fluid)	Control plates		Vacuum plates		Nitrogen plates	
	Zone diameter (cm)	Growth†	Zone diameter (cm)	Growth†	Zone diameter (cm)	Growth†
			Sarcina lutea			
0.25	2.1	Excellent	2.2	Good	2.3	Good
0.50	2.4	Excellent	2.4	Good	2.6	Good
			Micrococcus pyogenes			
0.25	2.2	Excellent	2.3	Fair	2.4	Fair
0.50	2.5	Excellent	2.5	Fair	2.5	Fair

* Applied on agar with 1.3 cm. disk.
† No initial growth was apparent when the sealed container was opened, whether the plates were control plates or vacuum or nitrogen packed after storage for 13 days at respective temperatures.

terial plates may result in an easier and more effective means of growing and counting anaerobes in the laboratory than is employed presently.

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28 June 1957

Growth Chamber with Light of Solar Intensity

Conventional plant growth chambers utilize primarily fluorescent lamps, which produce a maximum illumination of only 2000 to 2500 ft-ca (*1*). No descriptions have been found of chambers in which the intensities are comparable to those of full sunlight. Summer sunlight intensities in the United States at noon on relatively clear days range from around 9000 to 14,000 ft-ca, depending upon the exact time of year, altitude, latitude, and sky conditions. Therefore, experimental studies with plants having these high light requirements cannot be carried out in conventional chambers. This would include plants whose natural occurrence is restricted to open areas receiving full sunlight.

The performance of the chamber described in this report (Fig. 1) has been satisfactory, not only in its mechanically successful operation since November 1956, but also in that several herbaceous species requiring full sun for normal development have been grown from seedling to maturity without evidence of shade effects.

This chamber is a modification of an existing one, in which all parts except those required for illumination were present. It is 1.4 m wide, 1 m deep, and 1.1 m high. After a survey of commercially available lamps had been made, a battery of 36 G-E R-40 300-w reflector spots was chosen. The lamps were installed in porcelain bases having ball-and-socket joints (*2*), which were in turn clamped to a frame forming a square grid with 15-cm centers. Thus the bulbs were only 2.5 cm apart. Heat-resistant asbestos wiring was used throughout.

These lamps have an emissivity of 3500 total lumens and a nominal beam spread of 30 deg. The 10-deg center cone varies from 13,500 to 14,500 candlepower, with a drop to 6000 at the 20-deg circumference, and 2000 at the 30-deg circumference. Total lumens for a 10-deg cone are 330; for a 20-deg cone, 970; and a 30-deg cone, 1450. The approximate average initial intensity at 1.5 m is 560 ft-ca over a circle 23 cm in diameter, 440 ft-ca over a circle 45 cm in diameter, and 276 ft-ca over a circle 76 cm in diameter (*3*). The accumulated foot-candles from the overlapping intensity patterns of each of the 36 lamps varies from about 12,000 in the center of the grid to 8500 in the outer portion. Although intensities increase as the distance is reduced, the inverse square law does not hold because of the multiple light sources and the cone-shaped intensity pattern of each source. These calculated intensities have been verified by direct measurement. By slightly angling the lamps, the grid area at 1.3 m (on the floor of the chamber) can be made to receive almost uniform illumination.

The only other suitable sources located were mercury-type lamps such as the G-E B-H6 1000-w lamp of 65,000 lu, which is used in search-lights, and the G-E A-H9 3000-w lamp of 120,000 lu, which is used for high bay lighting. For some installations these lamps may be preferable to incandescent lamps. Drawbacks include the absence of built-in reflectors, the elaborate cooling system needed by the former and the size of the ballast for the latter. Uniform illumination would be difficult to achieve, and several lamps would be required for a chamber of the size described here. None of the street-lighting lamps investigated were satisfactory. Despite a range in size from 1000 to 25,000 lu these lamps were not small enough to permit the close spacing required to build up high intensities.

Approximately 70 percent of the energy used by a 300-w incandescent lamp is dissipated as heat energy. A water filter consisting of a box with 6-in. metal sides and a glass bottom was designed to remove most of this heat. Water inflow is through a perforated pipe across one side, and the outflow is through a series of holes drilled on the opposite side. Water depth is controlled by vertical spacing of the outlet holes.

In the range of wavelengths from 0.6 to 3.0 μ, the amount of radiation absorbed from sunlight by a layer of water 1 cm thick is 26.97 percent, while only 0.01 percent in the range from 0.2 to 0.6 μ is absorbed. For a layer 10 cm thick, 45 percent of the radiation from 0.6 to 3.0 μ is absorbed, while for a 100-cm layer, the amount of absorption is increased to only 63.34 percent. However, the 0.08-percent radiation absorbed in the range from 0.2 to 0.6 μ by a 10-cm

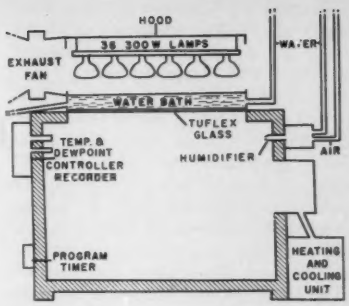

Fig. 1. Cross-sectional diagram of growth chamber 1.4 m wide, 1 m deep, and 1.1 m high.

layer is increased to 7.5 percent for a 100-cm layer (*4*). When a 10-cm layer is used in this chamber, heat radiation is reduced to a level comparable to that received from the sun. At 1.3 m from the source, radiation received is 1.1 g cal/cm² min, whereas at 0.9 m it is increased to 1.65 g cal/cm² min.

The floor is composed of a ¼-in. sheet of tempered plate glass (*5*) which has four times the resistance to thermo shock and three to five times the resistance to impact shock of ordinary plate glass. This glass permits 90 to 93 percent transmission in the visible spectrum, with a cut off between 0.31 and 0.36 μ and a slow fall beyond 1 μ.

A Foxboro dewpoint temperature and humidity recording and controlling system is used, in connection with a 750-w heater and a 1 hp refrigeration unit, each operated with a fan for forced circulation. Moisture is supplied by an atomizer utilizing compressed air at a pressure of 30 lb/in.² For most uses humidity control may not be necessary because of transevaporation, which occurs naturally within the chamber. A more satisfactory system, especially for low or high temperatures and humidities, would employ recirculating air, with the heating and cooling units located outside the box (*6*). It should be emphasized that Fig. 1 is diagrammatic and is thus suggestive of a variety of modifications.

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2. Swivelier No. 817.
3. *G-E Eng. Publ. LS-142* and G-E leaflet 1B-319-R-1.
4. N. E. Dorsey, *Properties of Ordinary Water-substance* (Reinhold, New York, 1940).
5. Libby-Owens-Ford Tuf-flex.
6. The collaboration of F. H. Bormann, J. P. Witherspoon, and C. H. Stephens, Jr., and support from the Emory University Research Committee and the U.S. Atomic Energy Commission [contract No. AT-(40-1)-2089] are acknowledged.

15 July 1957

Book Reviews

The Detection and Measurement of Infra-Red Radiation. R. A. Smith, F. E. Jones, R. P. Chasmar. Clarendon Press, Oxford, 1957 (order from Oxford University Press, New York). xiii + 448 pp. Illus. + plates. $11.20.

A recent British publication, *The Detection and Measurement of Infra-red Radiation,* has helped to fill a gap in our scientific literature. The authors are R. A. Smith, F. E. Jones and R. P. Chasmar. The book is one of a series of monographs on the physics and chemistry of materials published by the Clarendon Press at Oxford.

The book starts in a natural manner with a description of the infrared spectrum, a historical background, a survey of detection methods, and a review of the uses of infrared radiation. In the second chapter, various radiation laws are derived. At this point the authors introduce a certain amount of mathematical rigor. However, at no time is the book unduly theoretical. The physical approach has guided the authors, and a fairly succinct picture is given.

There is a chapter devoted to thermal detectors, in which the elementary mathematical theory underlying the thermocouple, bolometer, and pneumatic cell is given. Various instruments are also described, but perhaps not in the detail some might desire.

Considerable space is given to photodetectors. Those seeking a clear description of the photoconductive process will find it in this chapter. Thallium sulfide, lead sulfide, lead telluride, and lead selenide cells are discussed. Some of the more interesting new cells are omitted. Possibly the English suffer from classification restrictions, too.

Three chapters are devoted to fundamental limitations in detection. These, combined with the chapter on radiation laws, contain the real essence of the book. Various noise sources are described and related to fundamental phenomena. Brownian movement, Johnson noise, shot noise, current noise, flicker noise, other electrical noise, thermal fluctuations, radiation fluctuations, and minimum detectable power form the sections of the first of these chapters. The second deals with fluctuations in amplifiers and indicating instruments. This chapter will appeal to the electrical engineer interested in noise reduction. The third of these important chapters deals with the ultimate sensitivity of infrared detectors. Thermocouples, bolometers, pneumatic detectors, and photoelectric and photoconductors are treated.

Chapters are devoted to radiant sources, optical materials, and optical components. A good deal of reference data is to be found in these sections. Undoubtedly, these sections broaden the appeal of the book. However, it is my opinion that, since this material cannot be fully covered in such a book, it might better be left to a strictly reference source.

Separate chapters are also used to describe infrared spectrometers and amplifiers used with infrared detectors. The last chapter deals with atmospheric transmission. This chapter is very inconclusive, unfortunately, and does not include the recent data obtained in this country.

The book is excellently referenced, reads exceptionally well, and maintains mathematical rigor without losing the physical description.

Generally, the book is excellent and constitutes a long-needed reference on the subject. Perhaps it will put an end to the trivial reports now glutting the field, which are put out by engineering groups as they "discover" infrared.

D. J. Lovell

Greenwich, Connecticut

Traité de Microscopie. Instruments and techniques. A. Policard, M. Bessis, and M. Locquin. Masson, Paris, 1957. vi + 608 pp. Illus. F. 5200.

The first third of *Traité de Microscopie* discusses the structure and use of microscopes, with preference given to French and European instruments, although others are not excluded. Optics and aberrations are briefly treated, and light sources are rated in order of intensity, but without quantitative data. Microscopists are advised to clean their instruments daily, check them weekly, and have them overhauled once a year. May these instructions be followed! Advice is offered for the protection of microscopes against dust in dry, and fungus attacks in damp, hot climates.

Brightfield, darkfield, phase, Wild Varicolor phase, Nomarski's interference, infrared, ultraviolet, television, flying spot, particle sizing, polarization, and metallographic microscopes are described in varying detail, and measurement techniques and their associated errors are well covered.

"Recording" includes the camera lucida, photomacrography, photomicrography, microscopes with built-in cameras, special methods (such as bas-relief from solarization), and tilting mechanisms for stereo pictures. The use of dry and liquid filters is treated in detail. Emulsions, including color, and processing receive slight consideration. Electron, x-ray, proton, and ion microscopes, reconstruction microscopy by holographs, and a one-and-one-half-page bibliography complete this section.

The remaining two-thirds of the book covers methods. Preparation methods for fresh material are largely concerned with cells and fragments of blood. Phase microscopy and intravital staining are discussed. Of six references, five are on blood. The next ten pages are on dissociation, digestion, and mechanical separation of cellular constituents (four references). Fixation is then covered in 19 pages, with 18 references. Freeze-drying is discussed. Very little of the extensive work with the phase microscope on the effects of fixing fluids is mentioned.

"Microtomy" includes the paraffin and celloidin methods, the gelatin method, various kinds of microtomes, knife sharpening, sectioning, and frozen sectioning, and the chapter ends with a table of difficulties and ways to avoid them. Knife sharpness is discussed later under electron microscopy.

The standard staining methods are allotted 33 pages, with three of 22 references more recent than 1945. Metallic impregnation, mounting methods, and smear examination methods follow.

General histochemical methods and methods for proteins, nucleic acids, lipids, glucides, inorganic elements, enzymes, and pigments are covered in 88 pages; then special techniques are given for decalcification, depigmentation, microincineration, polarization microscopy, fluorescence microscopy, micromanipulation, autoradiography, ultracentrifugation, microelectrophoresis, electron microscopy, counting, and tissue collection and biopsy. A table of refractive indices, an 18-page vocabulary of French to German to English words, an index, and a table of contents complete the book.

In comparison with Langeron's *Précis de Microscopie,* this book seems less complete and is more difficult to use. Writ-

ing the material in two sections makes the treatment spotty. One finds the description of the microscopes in one place and their use in other parts of the book; filters are discussed in several places; objectives are discussed under microscope optics and defined under photomicrography, and so on.

The vocabulary could be improved by omitting the words which vary only slightly in spelling and including words like *manche à balai* ("joy stick"—that is, micromanipulator control) whose meaning is not obvious from the words themselves. Some of the preparation is a bit careless: *Kristall* is given as the English for *cristal,* some references include only month and year, a book reference lists the third author as the first, the origin of Fig. 4 is not acknowledged, and so on.

There is much valuable material in this book, which presents French microscopy as it is viewed by three experts.

OSCAR W. RICHARDS
American Optical Company

Corrosion and Wear Handbook for Water Cooled Reactors. TID 7006. D. J. DePaul, Ed. U.S. Atomic Energy Commission, 1957 (order from Government Printing Office, Washington, D.C.). 293 pp. $2.25, paper.

Corrosion and Wear Handbook for Water Cooled Reactors is the sixth report in an unclassified series on reactor technology sponsored by the Naval Reactors Branch of the Atomic Energy Commission.

The handbook supplies theoretical background as well as experimental data on corrosion and wear of materials in water-cooled nuclear reactors. These data were provided by both governmental and private organizations which were prime- or subcontractors for the *Nautilus* Submarine Reactor and the Shippingport Pressurized Water Reactor projects.

The book is organized in three parts. Part A (four chapters) states the problems of using high-purity, high-temperature water as a reactor coolant. This part generally discusses nuclear reactors for power plants, choosing reactor materials, fundamental facts of corrosion and wear, and water technology. Part B (four chapters) gives basic reference data for use in design work. Corrosion and wear properties of various materials and combinations of materials under specified conditions are listed, as are the effects of variable factors on corrosion and wear and on recommended testing procedures. Part C (six chapters) deals with such special problems as crevice, stress, and intergranular corrosion, and with application and manufacturing problems involving wear.

Dictionary of Microbiology. Morris B. Jacobs, Maurice J. Gerstein, William G. Walter. Van Nostrand, Princeton, N.J., 1957. 276 pp. $6.75.

The authors have been liberal in marking out the scope of this dictionary, the first in its field. It "defines the terms commonly used in microbiology and the related fields of bacteriology, mycology, virology, cytology, immunology and immunochemistry, serology and microscopy." The fence erected to define these areas proved to be permeable to many of the protozoa of medical importance, but most of the helminths were effectively excluded. There are an estimated 4700 entries, consisting mainly of brief definitions or descriptions, arranged in a pleasing double-column format with key words in bold-face type. An occasional helpful chart or diagram is included. Cross references appear to be ample.

There may be a need for an alphabetically arranged reference book in microbiology, but opinions will differ concerning the form it should take. Entries as brief as most of those in the present volume will certainly restrict its usefulness. Perhaps this degree of brevity was felt to be necessary in order to produce a book of moderate size. Nevertheless, space could have been saved by other means, such as the omission of numerous terms that are defined as well and more completely in an ordinary desk dictionary and the avoidance of unnecessary repetition in the description of the several species of one bacterial genus. The striving for brevity, with the breadth of scope indicated above, may have contributed to inadequate coverage (for example, *myeloblast* and *myelocyte* are included; *lymphoblast* and *erythroblast* are excluded) as well as to unfortunate ambiguities and outright errors of fact. Examples will be found in the definitions of *fluctuation test, macrophage,* and *vaccination, bacterial.*

A better effort than that represented by this book will have to be made before the question of the usefulness of a dictionary of microbiology can be adequately answered by practical test.

FRANCIS B. GORDON
Naval Medical Research Institute

The Modern Researcher. Jacques Barzun and Henry F. Graff. Harcourt, Brace, New York, 1957. xiii + 386 pp. $6.

This useful handbook for anyone who has to put his thoughts in writing, from a college freshman to a foundation president, is offered in the twofold conviction that poor expression is nothing more than poor thinking and that there is no substitute for hard work. All is explained—how to use a library, how to take notes from the books found there, how to compose a periodic sentence, how to give a paper a beginning and a middle and an end, how to correct galley proofs. In addition, considerable space is devoted to a discussion of history, its methods of research, its logic, and its laws (if such there are). This discussion represents, at least in part, good popularizing, but it is never made clear just why it is included in the book, unless the reason is that the two authors are both also professional historians.—J. T.

A History of Luminescence from the Earliest Times until 1900. vol. 44 of *Memoirs* of the American Philosophical Society. E. Newton Harvey. American Philosophical Society, Philadelphia, Pa., 1957. xiii + 692 pp. Plates. $6.

When an electron in a molecule or atom is raised to a high-energy level and then drops back again, radiant energy is emitted. In some cases the emitted rays are visible to the human eye. When heat furnishes the energy for excitation, as in the sun, a candle, or tungsten filament, low-efficiency incandescence is observed. When the excitation energy is supplied from other sources, such as a chemical reaction, luminescence or "cold light" is observed. Examples of luminescence are numerous. There is *electroluminescence,* resulting from a flow of current (fluorescent lights, aurora borealis, *ignis lambens,* and St. Elmo's fire). *Phosphorescence* is the lasting luminescence which results from the exposure of a substance to irradiation. When the light emission is of very short duration (10^{-9} sec) it is known as *fluorescence. Thermoluminescence* is the emission of light on slightly heating a substance to liberate excited electrons from a trapped state. *Triboluminescence* and *piezoluminescence* are light emissions that result from rubbing and pressing a material, respectively.

There are many other examples of luminescence, including light emission by organisms (bioluminescence), and the purpose of the present book "is to trace the discovery and the ideas regarding these lights without heat from the earliest times until the end of the 19th century." The book is divided into three parts. In the first part a general survey of our knowledge of luminescence is given, while parts 2 and 3 deal with special types of luminescence associated with the nonliving and the living world, respectively.

For students of luminescence, physical or biological, this book is required reading. To others, it will be the fascinating

story of historical reports on the glowing of cats' eyes, the light of the warrior's eyes during battle, Aristotle's observations on light which appears when the eyeball is pressed, and so forth. The first recorded explanations of the phosphorescence of the sea, wood, and flesh are ingenious and fantastic when compared with contemporary beliefs. It is surprising how frequently luminescence stimulated the great men of all branches of science, and, as Newton Harvey points out, the "history of luminescence is a guide to the history of science in general." It might also be said that men of literature were influenced by luminescence: for example, Dante, in the *Inferno* ("Fire-flies innum'rous spangling o'er the vale") or Shakespeare, in *Pericles* (1609) ("Like a glow-worm in the night the which hath fire in darkness, none in light.")

Harvey, who has spent more than 40 years in the study of luminescence, has provided us with a very readable and detailed history of a subject which is fast becoming the universal method of illumination and communication.

W. D. McElroy

Johns Hopkins University

Concepts of Force. A Study in the Foundations of Dynamics. Max Jammer. Harvard University Press, Cambridge, Mass., 1957. viii + 269 pp. $5.50.

Physical theories operate with concepts which, though free creations of the human mind in their strict logical character, are usually found to have their roots in human experience extending over long periods of time. Hence, critical examination of them is a peculiar combination of historical and methodological research. This is particularly true of the concepts of mechanics, the oldest of physical theories. The attitude of scientists toward these has undergone great changes from the days of Greek science to our own. It is the purpose of the author of *Concepts of Force* to trace the development of the idea of force from its meaning in ancient physics to that in 20th-century science.

The story is a long and complicated one, demanding great skill on the part of the writer in the choice of the relevant elements in an enormous body of more or less obscure material. He has to search for the origin of the idea in the groping attempts of our ancestors to give an explanation for motion in general, based on the analogy with human exertion and activity represented in such terms as *effort, force, power, work*. He must then proceed to note how these ideas were refined by abstract thinkers, given quantitative status, and made useful for the solution of practical problems. Finally he has to show how, in the process of refinement, the concept of force reaches the stage where it can be eliminated from the logical structure of the theory without hampering the deductions of the latter and becomes a mere heuristic device whose precise philosophical meaning no longer has significance.

The author has obviously studied the literature with great thoroughness. Historians will approve his dependence, in most cases, on original rather than secondary sources. His interpretations are carefully made, though he is candid in admitting the ever-present difficulty of really understanding what ancient writers on mechanics meant by what they said. This problem makes the history of science an involved and uncertain discipline, though perhaps only a few degrees more so than history in general. Two-thirds of the book is devoted to the history of the force idea, from Galileo to modern times. There is a particularly good discussion of the problem of the possible influence of theological ideas on Newton's concept and of the converse problem of the influence of his mechanics on theological thought in the 18th century. Probably not enough attention is paid to Newton's third law, which has had such an enormous influence on the development of modern physics through the conservation theorems.

I am glad to see adequate justice done to the ingenious ideas of Boscovich (1745), with his point centers of force. Moreover, there is an excellent presentation of the famous controversy between the followers of Descartes and of Leibnitz on the "true" measure of the effect of a force. Through the careful critiques of Hertz, Mach, and Poincaré, the logical status of force in modern physics has been completely clarified, though the melancholy fact remains that many writers of elementary textbooks are still not aware of this. It is to be hoped that the publication of books like that of Jammer will help to rectify this situation.

R. B. Lindsay

Brown University

New Books

The Shakespearean Ciphers Examined. An analysis of cryptographic systems used as evidence that some author other than William Shakespeare wrote the plays commonly attributed to him. William F. Friedman and Elizabeth S. Friedman. Cambridge University Press, London, 1957. 320 pp. $5.

Marysvale, Utah, Uranium Area. Geology, volcanic relations, and hydrothermal alteration. Special Paper 64. Paul F. Kerr, Gerlad P. Brophy, Harry M. Dahl, Jack Green, Louis E. Woolard. Geological Society of America, New York, 1957. 212 pp.

Angular Momentum in Quantum Mechanics. A. R. Edmonds. Princeton University Press, Princeton, N.J., 1957. 154 pp. $3.75.

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Chemistry for the Laboratory. Alfred B. Garrett, Joseph F. Haskins, Thor R. Rubin, Frank H. Verhoek. Ginn, Boston, ed. 2, 1957. 423 pp. $4.25.

Language: An Enquiry into Its Meaning and Function. Ruth Nanda Anshen, Ed. Harper, New York, 1957. 384 pp. $6.

Religion without Revelation. Julian Huxley. Harper, New York, 1957. 252 pp. $4.

The Divine Quest in Music. R. W. S. Mendl. Philosophical Library, New York, 1957. 265 pp. $7.50.

Handbook of Chemical Data. F. W. Atack, Ed. Reinhold, New York, 1957. 629 pp. $6.75.

The Carbohydrates. Chemistry, biochemistry, physiology. Ward Pigman, Ed. Academic Press, New York, 1957. 919 pp. $20.

Conservation. An American story of conflict and accomplishment. David Cushman Coyle. Rutgers University Press, New Brunswick, N.J., 1957. 296 pp. $5.

Meetings and Societies

Humanist and Ethical Union

Members of the second Congress of the International Humanist and Ethical Union, from 21 countries, were laymen with practical social interests and academic persons from biological, sociological, and philosophical fields. The physical sciences were poorly represented, but the social impact of the physical sciences dominated and shaped the thinking of the congress.

In his presidential address, "Mankind now," Lord Boyd Orr enunciated the general theme of the congress: science, which has advanced farther in the last 50 years than in the previous 2000, is pushing mankind into a new age, which will differ from the early 19th century by more than that era differed from early extinct civilizations; the only hope for the survival of our civilization is in radical readjustment to the new conditions which modern science has created; a humanist movement is required, by its faith in science and in human responsibility, to play a leading part in effecting this radical readjustment. Boyd Orr took as the three main tasks of readjustment the abolition of war, the distribution of plenty, and the arrest of the growth of population, and he insisted, finally, on the all-important character of freedom of thought and communication as the source of science and of progress and as the characteristic contribution of humanism.

T. T. ten Have (professor of psychology and social ethics at the University of Amsterdam), in an address on "The humanistic venture in our time," made a more elaborate analysis of the present situation. Describing the prominent and alarming forms of disintegration and of integration, he related them to liberation, reevaluations, and recognition of new responsibilities and concluded that man will be educated by an increasing awareness of the situation and will convert his loss of rootedness into a new relatedness, rationally and emotionally sound.

J. Bronowski, addressing the congress on "Science and responsibility," rebutted the thesis that science is only a means, which should be subordinated to ends imposed dogmatically by the traditional moral codes. Truth is the paramount value from which all other values are derived; it is the drive for knowledge which makes men human, for knowledge is the tool by which they gain the freedom to be most fully themselves, and science has made fulfillment the driving motive of our civilization. It is, therefore, the responsibility of the scientist to form new moral codes appropriate to our civilization and to create a universal ethic by educating himself and the public in the universal applicability of scientific method.

H. J. Muller, speaking on "Radioactive fallout in relation to human progress," compared the estimated harmful effects of nuclear tests already held with those resulting from unavoidable natural causes and from medical practice, in order to show that the widespread public protest expressed not so much indignation at the tests as a dread of nuclear war and therefore of nuclear weapons. He argued that America's development of nuclear weapons had saved the Western world and that the present situation of stalemate gave the world, for the first time in history, a precarious security. Instead of seeking an illusory return to conventional arms, he said, the great powers should maintain the stalemate by removing the barriers of secrecy in working out further development of nuclear weapons. Meanwhile, the time of present restraint should be used to lay the foundations of lasting peace. Muller had just come from a world conference of scientists at Pugwash, the estate of Cyrus Eaton in Nova Scotia, which followed the Einstein-Russell initiative.

The congress was divided into four sections to discuss papers on the humanist outlook on philosophy, personal life, social life, and organization. In the main paper on philosophy, Horace Friess (professor of philosophy at Columbia University) started from the position of Julian Huxley at the first congress—namely, that through the development of science, the possibility of man's assuming a hitherto unimagined responsibility for the direction of life on this planet stands out against the alternative of present drift into a seriously deteriorated condition. He quoted from the report to the American Association for the Advancement of Science of the Interim Committee on the Social Aspects of Science to indicate the unsatisfactory present social conditions for the growth and application of science. In deprecating prevalent attitudes and fears and calling for a creative relationship between specialized scientific and general human intelligence, he suggested the cooperation between specialist and patient in modern psychotherapy as the type of interplay needed to promote a more humanistic use of science. The report of this section recognized science as the means of increasing human fulfillment and as the basis and test of humanist convictions but included a warning against utopian thinking. The section adopted a motion by Huxley to form a panel for the preparation of a "Humanist manifesto," which should include a statement of the grounds and contents of humanist beliefs, of the humanists' ultimate and immediate aims, and of the basic differences between humanism and other major contemporary systems of thought and belief.

The Section on Personal Life expressed qualified confidence in man's sustained endeavor, as he learns from experience, to develop human resources, capacities, and energies and to direct them to the achievement of higher levels of human relationship, greater personal fulfillment, and more responsible social institutions. The topics discussed by the section were education, marriage and family life, facing tragedy, and social ethics. On education, there was insistence on the mutuality of the child-adult relationship, on honesty in both the approach to the child and the knowledge imparted, and on respect for the validity of the learner's choices. On social ethics, the group faced the conflicts and pressures generated by our increasingly complex societies and repudiated dogmatic solutions of the problems involved. Cultivation of a sensitive ethic, of informed insight, of a sense of personal identity, and of awareness of interdependent responsibility was the remedy, it stated, against the pressures of society in the direction of conformity and was the way to a full release of human energies.

The Section on Social Life, recognizing both that humanists are committed by their convictions and aims to take an active part in political issues and that it is out of the question for humanist movements to give allegiance to any political party, declared in its report that the first task of a humanist movement must be to work for the conditions necessary for free inquiry and to strive to remove the obstructions put in the way of scientific investigation of social problems by, for example, vested interests and dogmatic attitudes. In this connection, full support for the work of UNESCO was urged.

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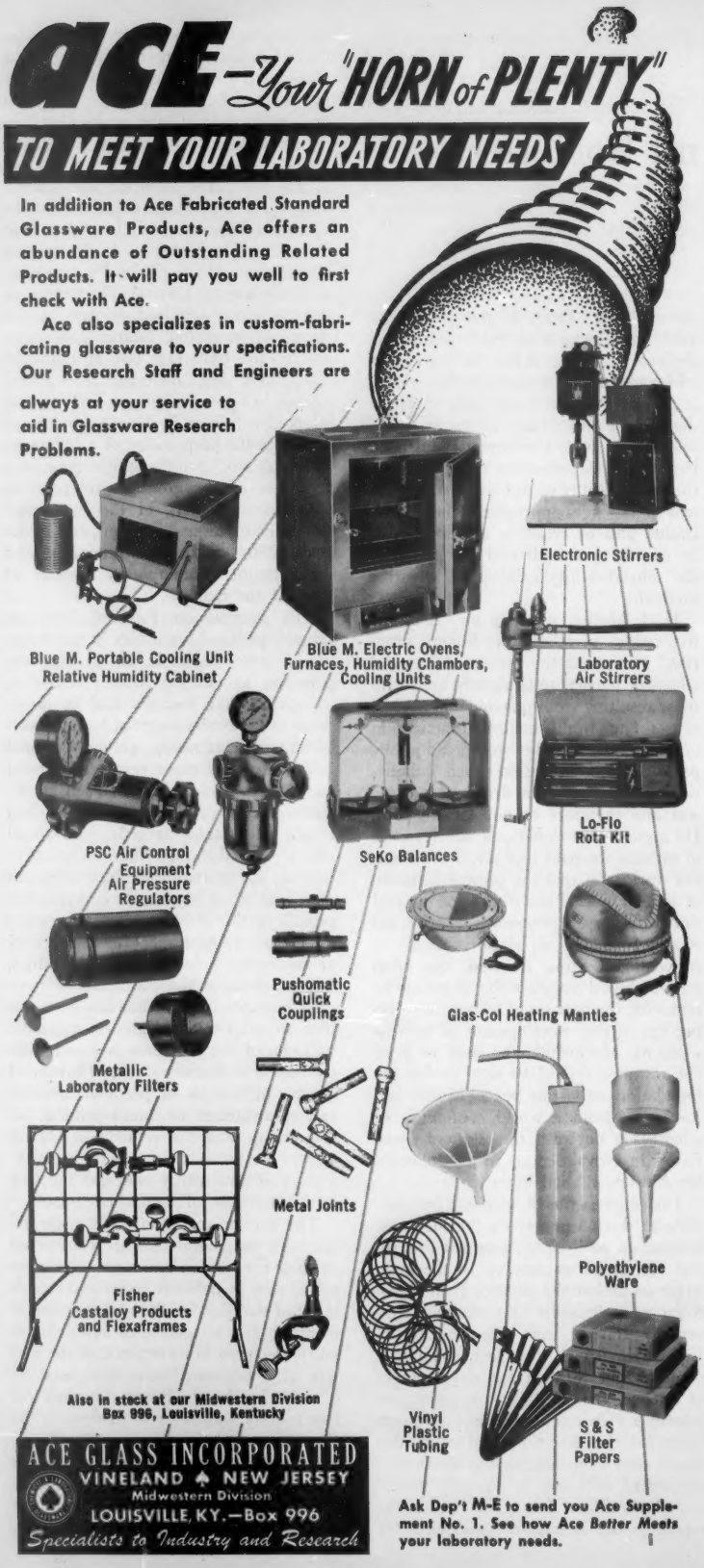
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Other points stressed were the importance of bringing an adequate concern for human values into the developing science of industrial management and the need for experimentation in the structure and control of industrial undertakings; support for the organizations and agencies studying and dealing with the fundamental problem of population; and the need to keep the political, social, and cultural development of the poorer countries in step with their economic expansion.

At the final plenary session, the congress adopted, for action, a statement which posed the problem of defense in the present arms situation. "We all have vital interests in the world to be defended and extended: how can it be done without wrecking the whole human enterprise? That is the crude question which demands a set of realistic answers." Our thinking on this question is evidently confused, precipitate, and frightened. The situation is unprecedented, and our habitual political ideas and ideals have become too suddenly obsolescent for clear and united thinking relative to new and adequate forms of political behavior to emerge without a very special and informed effort. What is wanted first of all, to focus and enlighten world thinking on this most vital human question, is a world commission of experts of the highest caliber in the fields of politics, sociology, philosophy, and the sciences to examine the problem of the defense and development of legitimate interests in all its aspects. This has become a common human problem, not merely the problem of sovereign states or of power blocs, and it is this new situation that requires new thinking, which must be world thinking. The congress adopted the statement and authorized the executive committee of the International Humanist and Ethical Union to try to mobilize an informed public demand for such a conference or commission.

H. J. BLACKHAM
Ethical Union, London, England

Structure of the Nucleus

The Robert A. Welch Foundation will sponsor a research conference on The Structure of the Nucleus in Houston, Tex., 20–22 November. Some 500 scientists from all over the world are expected to attend.

The program includes: Glenn T. Seaborg, "Man-Made Elements"; D. H. Wilkinson, "The Structure of the Light Nuclei"; Eugene P. Wigner, "Isotopic Spin—A Quantum Number for Nuclei"; J. Hans Jensen, "Progress in the Theory of Nuclear Structure"; Ernest O. Lawrence, "Some Recent Developments in Nuclear Science"; L. Van Hove, "The Structure of Nuclear Matter as a Prob-

lem in the Quantum Theory of Many Particle Systems"; and W. F. Libby, "Nuclear Techniques in Chemistry."

For information write to the Robert A. Welch Foundation, 20th Floor Bank of the Southwest Building, Houston 2, Tex.

Technical Writers

The Society of the Association of Technical Writers and Editors will hold its fifth annual national convention 13–15 November at the Statler Hotel in New York. This is the first convention held since the merger of the Association and the Society of Technical Writers. The theme of the convention will be the role of the publications expert in advancing the frontiers of science. For information, communicate with Donald R. Alt, 3506 94th St., Jackson Heights 72, N.Y.

International Cancer Congress

The International Union Against Cancer will award a limited number of travel grants to enable young scientists to attend the Seventh International Cancer Congress in London, England, 6–12 July 1958. Applicants under 35 who do not yet hold senior appointments will receive preference if they have made significant contributions to cancer literature.

The grants will cover part or all of the travel expenses from and to the country of residence, but no subsistence allowance will be provided. For application forms write to I. Berenblum, Chairman, Committee for Young Scientists, U.I.C.C., Weizmann Institute of Science, Rehovoth, Israel.

Forthcoming Events

November

25–27. American Acad. for Cerebral Palsy, 11th annual, New Orleans, La. (R. R. Rembolt, Iowa Hospital–School State University of Iowa, Iowa City.)

25–27. Physics and Dynamics of Fluids, APS, Bethlehem, Pa. (F. N. Frenkiel, Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.)

26–28. Central Assoc. of Science and Mathematics Teachers, 57th annual, Chicago, Ill. (L. Panush, Henry Ford High School, Detroit 19, Michigan.)

28–29. American Physical Soc., St. Louis, Mo. (K. K. Darrow, Columbia Univ., New York 27.)

29–30. American Soc. of Animal Production, annual, Chicago, Ill. (H. H. Stonaker, Animal Husbandry Dept., Colorado State Univ., Fort Collins.)

December

1–6. American Soc. of Mechanical Engineers, annual, New York, N.Y. (C. E. Davies, ASME, 29 W. 39 St., New York 18.)

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1–15. Bahamas Medical Conf., 4th, Nassau, Bahamas. (B. L. Frank, 1290 Pine Ave., W. Montreal, Que., Canada.)

2–5. American Rocket Soc., annual, New York. (J. J. Harford, ARS, 500 Fifth Ave., New York 36.)

2–5. Entomological Soc. of America, annual, Memphis, Tenn. (R. H. Nelson, ESA, 1530 P St., NW, Washington 5.)

3–4. Human Factors in Systems Engineering, symp., Philadelphia, Pa. (C. Fowler, American Electronic Labs., 121 N. 7 St., Philadelphia.)

4–8. American Psychoanalytic Assoc., New York, N.Y. (J. N. McVeigh, APA, 36 W. 44 St., New York 36.)

4–10. American Acad. of Optometry, annual, Chicago, Ill. (C. C. Koch, 1506–1508 Foshay Tower, Minneapolis 2, Minn.)

5–7. Texas Acad. of Science, annual, Dallas. (G. C. Parker, Education Dept., Texas A&M College, College Station.)

5–8. American College of Cardiology, 6th interim, Cincinnati, O. (P. Reichert, ACC, Empire State Bldg., New York 1.)

6–7. Oklahoma Acad. of Science, annual, Enid. (J. T. Self, Dept. of Zoology, Univ. of Oklahoma, Norman.)

7–8. American Acad. of Dental Medicine, New York, N.Y. (S. Ross, 136 E. 36th St., New York 16.)

8–11. American Inst. of Chemical Engineers, annual, Chicago, Ill. (F. J. Van Antwerpen, AIChE, 25 W. 45 St., New York 36.)

9–11. Fluorides Symp., Cincinnati, Ohio. (Secretary, Inst. of Industrial Health, Kettering Laboratory, Eden and Bethesda Aves., Cincinnati 19.)

9–13. Eastern Joint Computer Conf., Washington, D.C. (H. H. Goode, Dept. of Electrical Engr., Univ. of Michigan, Ann Arbor.)

9–22. Southeast Asia Soil Science Conf., 1st, Manila, Philippines. (I. G. Valencia, Bureau of Soils, P.O. Box 1848, Manila.)

10–11. Water Quality Control for Subsurface Injection, 2nd annual conf., Norman, Okla. (M. L. Powers, Extension Div., Univ. of Oklahoma, Norman.)

13–14. Association for Research in Nervous and Mental Disease, 37th annual, New York, N.Y. (R. J. Masselink, 700 W. 168 St., New York 32.)

15–18. American Soc. of Agricultural Engineers, Chicago, Ill. (J. L. Butt, ASAE, St. Joseph, Mich.)

17–19. Nuclear Sizes and Density Distributions Conference, Stanford, Calif. (R. Hofstadter, Stanford Univ., Stanford, Calif.)

19–21. American Physical Soc., Stanford, Calif. (W. A. Nierenberg, Univ. of California, Berkeley 4.)

26–27. Northwest Scientific Assoc., annual, Spokane, Wash. (W. B. Merriam, Geography Dept., State College of Washington, Pullman.)

26–30. American Assoc. for the Advancement of Science, annual, Indianapolis, Ind. (R. L. Taylor, AAAS, 1515 Massachusetts Ave., NW, Washington 5.)

The following 43 meetings are being held in conjunction with the AAAS annual meeting.

AAAS Acad. Conference, annual (Father P. H. Yancey, Spring Hill College, Mobile, Ala.). 28 Dec.

AAAS Cooperative Committee on the Teaching of Science and Mathematics (F. B. Dutton, Dept. of Chemistry, Michigan State Univ., East Lansing). 27 Dec.

Alpha Chi Sigma (R. L. Hicks, 1130 E. Jefferson St., Franklin, Ind.).

Alpha Epsilon Delta (M. L. Moore, 7 Brookside Circle, Bronxville, N.Y.). 28 Dec.

American Assoc. of Hospital Consultants (J. B. Norman, 8 South Church St., Greenville, S.C.).

American Astronomical Soc. (J. A. Hynek, Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge 38, Mass.). 27–30 Dec.

American Geophysical Union (E. M. Brooks, Dept. of Geophysics, St. Louis Univ., St. Louis 8, Mo.).

American Medical Assoc. Committee on Cosmetics (Mrs. V. L. Conley, AMA, 535 N. Dearborn St., Chicago, Ill.). 28–29 Dec.

American Meteorological Soc. (K. C. Spengler, AMS, 3 Joy St., Boston, Mass.).

American Nature Study Soc., annual (R. L. Weaver, School of Natural Resources, Univ. of Michigan, Ann Arbor). 26–30 Dec.

American Physiological Soc. (F. A. Hitchcock, Dept. of Physiology, Ohio State Univ., Columbus 10.)

American Psychiatric Assoc. (M. Greenblatt, Massachusetts Mental Health Center, 74 Fenwood Rd., Boston 15). 29–30 Dec.

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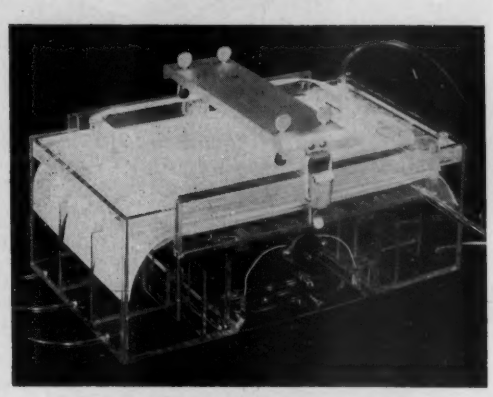

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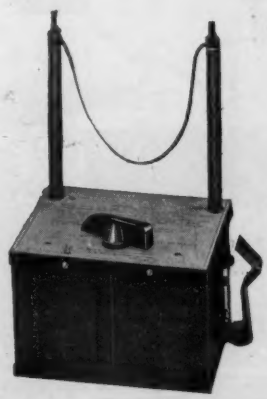

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American Soc. of Naturalists (B. Wallace, Biological Lab., Cold Spring Harbor, Long Island, N.Y.).

American Statistical Assoc. (V. L. Anderson, Statistical Lab., Purdue Univ., Lafayette, Ind.).

Association of American Geographers (L. L. Ray, U.S. Geological Survey, Washington 25).

Association for Computing Machinery (J. E. Robertson, Digital Computer Lab., Univ. of Illinois, Urbana).

Astronomical League (W. Garnatz 2506 South East St., Indianapolis).

Beta Beta Beta (Mrs. F. G. Brooks, P.O. Box 336, Madison Sq. Station, New York 10). 27 Dec.

Biometric Soc., ENAR (T. A. Bancroft, Dept. of Statistics, Iowa State College, Ames).

Conference on Scientific Editorial Problems, annual (G. L. Scielstad, Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.). 26–30 Dec.

Conference on Scientific Manpower, annual (T. J. Mills, National Science Foundation, Washington 25). 30 Dec.

Ecological Soc. of America (A. A. Lindsey, Dept. of Biological Sciences, Purdue Univ., Lafayette, Ind.). 27–29 Dec.

Metric Assoc. (J. T. Johnson, 694 West 11 St., Claremont, Calif.).

National Acad. of Economics and Political Science (D. P. Ray, Hall of Government, George Washington Univ., Washington, D.C.).

National Assoc. of Biology Teachers, annual (Miss I. Hollenbeck, Southern Oregon College of Education, Ashland). 26–31 Dec.

National Assoc. for Research in Science Teaching (G. G. Mallinson, Western Michigan College, Kalamazoo). 26–30 Dec.

National Assoc. of Science Writers (J. Troan, *Pittsburgh Press,* Pittsburgh, Pa.).

National Council of Teachers of Mathematics (P. Peak, College of Education, Indiana Univ., Bloomington). 27 Dec.

National Geographic Soc. (W. R. Gray, NCS, 16th and M Sts., NW, Washington 6). 29 Dec.

National Science Teachers Assoc. (R. W. Schulz, Emmerich Manual Training High School, 2405 Madison Ave., Indianapolis 25). 26–30 Dec.

National Speleological Soc. (Brother G. Nicholas, LaSalle College, 20th and Olney Aves., Philadelphia 41, Pa.) 28 Dec.

Philosophy of Science Assoc. (C. W. Churchman, Case Inst. of Technology, Cleveland, Ohio).

Scientific Research Soc. of America, annual (D. B. Prentice, 56 Hillhouse Ave., New Haven 11, Conn.). 27 Dec.

Sigma Delta Epsilon, annual (Miss M. Chalmers, Dept. of Chemistry, Purdue Univ., Lafayette, Ind.). 26–30 Dec.

Sigma Pi Sigma (M. W. White, Pennsylvania State Univ., University Park). 27 Dec.

Society for the Advancement of Criminology (D. E. J. MacNamara, New York Inst. of Criminology, 40 E. 40 St., New York 16). 27–28 Dec.

Society for General Systems Research, annual (R. L. Meier, Mental Health Research Inst., Ann Arbor, Mich.).

Society for Industrial Microbiology, Washington Section (W. N. Ezekiel, Bureau of Mines, Washington 25).

Society for Investigative Dermatology (H. Beerman, Univ. of Pennsylvania School of Medicine, Philadelphia 3), 28–29 Dec.

Society of the Sigma Xi, annual (T. T. Holme, 56 Hillhouse Ave., New Haven 11, Conn.). 27 Dec.

Society of Systematic Zoology, annual (R. E. Blackwelder, Box 500, Victor, N.Y.). 26–31 Dec.

United Chapters of Phi Beta Kappa, annual address (C. Billman, 1811 Q St., NW, Washington, D.C.). 27 Dec.

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27. Association for Symbolic Logic., Cambridge, Mass. (J. Barlaz, Rutgers Univ., New Brunswick, N.J.)

27–28. Linguistic Soc. of America, Chicago, Ill. (A. A. Hill, Box 7790, University Station, Austin 12, Tex.)

27–30. American Finance Assoc., annual, Philadelphia, Pa. (G. E. Hassett, Jr., New York Univ., 90 Trinity Pl., New York 6.)

28–29. American Folklore Soc., annual, Chicago, Ill. (M. Leach, Box 5, Bennett Hall, Univ. of Pennsylvania, Phila. 4, Pa.)

28–30. American Anthropological Assoc., annual, Chicago, Ill. (W. S. Godfrey, Jr., Logan Museum, Beloit College, Beloit, Wis.)

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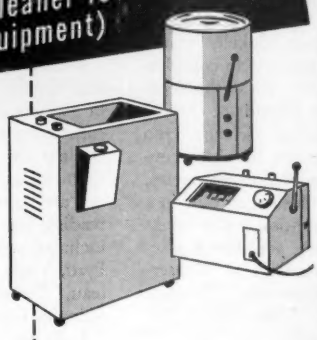

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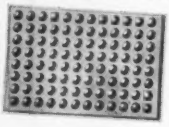

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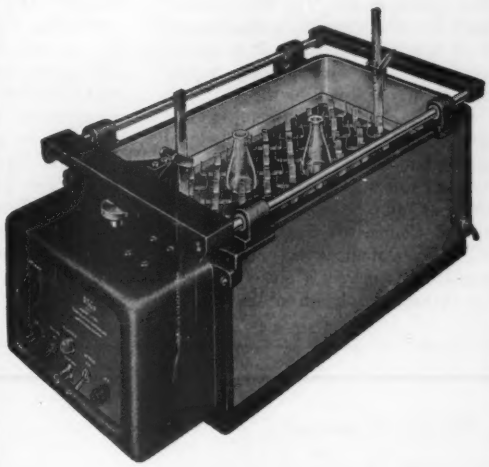

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LETTERS

The editors take no responsibility for the content of the letters published in this section. Anonymous letters will not be considered. Letters intended for publication should be typewritten double-spaced and submitted in duplicate. A letter writer should indicate clearly whether or not his letter is submitted for publication. For additional information, see Science **124**, *249 (1956) and* **125**, *16 (4 Jan. 1957).*

Science and Literature

The article "Literature, Science, and the Manpower Crisis," by Joseph Gallant [*Science* **125**, 787 (1957)] has been brought to the attention of our organization.

It is unfortunate that a magazine which goes under the title *Science* should be so unscientific in checking an article which it publishes. It is no less unfortunate that a supposedly responsible teacher of English, the chairman of a high-school department, should know so little about his own national organization.

Gallant refers to the *Combined Book Exhibit* as "an official publication of the National Council of Teachers of English." The statement is untrue. This pamphlet was merely a give-away item at a commercial booth at an NCTE convention; the advertisers had the privilege of displaying and advertising any books they chose, just as do exhibitors at a science convention. The official publications of NCTE are our four magazines and the publications listed in our catalog; even a glance at this catalog would have shown that the *Combined Book Exhibit* was not included.

Gallant is apparently unaware of the three reading lists that *are* official NCTE publications: *Adventuring With Books,* for elementary pupils; *Your Reading,* for junior-high pupils; and *Books For You,* for the senior-high level. A casual examination of these booklets would have changed Gallant's article considerably. In the first booklet, under the headings "Biology—The World of Living Things" and "Physical Science," no fewer than 130 titles are listed, in contrast to only 27 in a section on poetry, nine in a section on music, and nine in a section on art. In addition, other books on scientific subjects are listed elsewhere, under such headings as "Conservation and Natural Resources," "Persons, Places, and Things," "The World Today," and "Biography."

In the junior-high list are 152 titles, under the headings "Science Fiction," "Science and Scientists," "Inventions and Inventors," and "Fun and Meaning in Math." Other books on science appear in other parts of this list. In contrast, there are 56 books on music and musicians, 23 in a group called "Back Stage With Authors."

The senior-high list is classified differently; hence, a less precise count is possible. However, in one section alone—"I Read To See with the Eyes of Science"—there are 45 titles. In another—"I Read To Feel the World's Life"—there are books by our or about two of Gallant's favorites, Roy Chapman Andrews and Carl Akeley, as well as over 200 others, many directly related to science.

Gallant mentions a number of authors who should, in his opinion, be included in reading lists. Before jumping to the conclusion that they are not included, Gallant should have observed that the following among his recommended authors are represented in current NCTE reading lists and that others have been included in former lists: Andrews, Beebe, Byrd, Teale, Heyerdahl, Ditmars, Cousteau, Tazieff, Hogben, Linton, Jaffe, Shippen, Carson, and Ceram.

I do not choose to debate Gallant's main point that it is the English teacher's job to recruit scientists and to encourage still more emphasis on science than already exists—although a great deal can be said on both sides of this question.

J. N. HOOK

National Council of Teachers of English, Champaign, Illinois

It would be pointless to debate with Hook on the semantics of the word *official* as used in his third paragraph. The Council had a committee of its members listed as being in charge of the book exhibit at the convention. The Council cannot shrug off responsibility for a "give-away" which consisted of 80 printed pages of annotated book listings and which, moreover, was mailed on request months after the national convention and in a specially prepared envelope. Such a booklet, given away gratis, substantially competed with the Council's other reading lists, whose excellence is unquestionable.

The point made in my article, however, did not deal with committee supervision in the National Council of Teachers of English or with the effective educational work performed by Hook's and my organization. It pointed out the implications of the fact that *any* recommended bibliography in reading for the high school should give so little emphasis to science and should fail to list a single scientific title under the category "Understanding the Universe," which was given over entirely to books of devotion and ritual. This interpretation of "understanding the universe" raises a graver semantic question for the Council and

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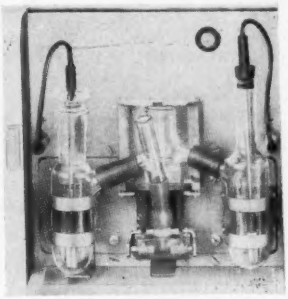

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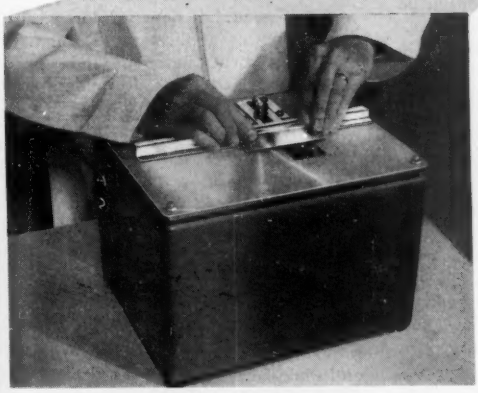

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JOSEPH GALLANT

Mount Vernon, New York

The "Abominable Snowman"

It is probable that the footprints that have been reported from the snows of the Himalayas as being those of the "Abominable Snowman" may have been made by several orders of mammals [W. L. Straus, Jr., *Science* **123**, 1024 (1956)]. In April 1953, tracks that looked like the photographs published in several popular magazines as being those of the "Abominable Snowman" were seen by the writer along the snow-covered trail to Baltistan, near Sonamarg, Kashmir. Some of the tracks were old, and some were fresh. The fresh tracks were large —4 to 6 inches wide and 10 to 14 inches long—and appeared to be made by a biped. In some of the fresher tracks the imprint of the toes became more and more pronounced as one followed the track, and then the toes disappeared and the tracks became larger. The bottom of the new and larger tracks showed a pattern like a rough weave but within a few yards became smooth and free from any distinguishing marks.

The tracks were made by men wearing snow sandals to protect their feet, not from the snow but from ice crystals that form from thawing and freezing. These sandals were woven of a plant that seemed to be much like the cattail, *Typha*. The plant grows in marshy areas and is cut in the fall and dried, but before it is too dry it is woven into a crude sandal. These snow sandals are worn by many inhabitants, either because they are too poor to buy leather or because they belong to a Buddhist sect that will not use leather. The sandals first wear under the toes, so the imprint of the toes is clear in the snow. When the wear goes too far, the foot-covering is discarded and the track changes suddenly. Discarded sandals were examined but were not saved, for the "Abominable Snowman" was considered to be the product of the imagination of men who saw "animal" tracks that had been enlarged by melting of the snow. Although the use of such snow sandals may be a local custom, it is quite possible that some of the tracks reported by explorers were made by men wearing the type of sandal described here.

ROBERT K. ENDERS

Department of Biology, Swarthmore College, Swarthmore, Pennsylvania

EQUIPMENT NEWS

The information reported here is obtained from manufacturers and from other sources considered to be reliable. Science *does not assume responsibility for the accuracy of the information. All inquiries concerning items listed should be addressed to* Science, *Room 740, 11 W. 42 St., New York 36, N.Y. Include the name(s) of the manufacturer(s) and the department number(s).*

■ COMPARATOR MICROPHOTOMETER, for measurements on photographic plates, uses a tiny mirror to deflect light from the line being measured, while light from the remainder of the field is used to project an image. The measuring optics are able to resolve the double component of the iron "triplet" at 3100 A when the linear separation on the plate is 28 μ. Scattered light is less than 0.5 percent. The electrical output of the multiplier phototube is measured by a servo slide-wire assembly. An electronic control circuit automatically selects the point of minimum transmission of the spectrum line and stops the scanning operation to permit reading. (Jarrell-Ash Co., Dept. S668)

■ SWEEP OSCILLATOR has two ranges, 10 to 500 and 400 to 950 Mcy/sec. Two series of calibration marks are provided at harmonic frequencies of 5- and 50-Mcy/sec crystal-controlled oscillators. Sweep-width is variable from 5 to 40 Mcy/sec with sweep rate approximately 60 cy/sec. The output waveform contains less than 5 percent harmonic distortion at full output. (Kay Electric Co., Dept. S670)

■ POWER SUPPLY furnishes high-voltage excitation for multiplier phototubes. Output voltage ranges from 500 to 5000 v d-c. The unit is designed for scintillation-counting applications. Regulation is 0.005 percent, and noise and ripple are 50 mv peak-to-peak. A standard cell furnishes voltage reference. Current capacity is 10 ma. (Hammer Electronics Co., Inc., Dept. S671)

■ FUME HOOD is fabricated with spherical corners throughout to eliminate points where hazardous deposits may accumulate. The hoods are made of stainless steel integrally welded and ground smooth. Service connections are mounted on raised circular platforms that are pressed into the sheet metal. Cup sinks and sink bowls are integrally welded. (Warren Corporation, Dept. S673)

■ ZONE MELTING device for purifying silicon eliminates container contamination by eliminating the container. The silicon rod to be purified is supported rigidly at its ends, while the molten zone, which is swept along the rod by induc-

tive heating, is supported only by surface tension. Stability of the molten zone is achieved by proper proportioning of load and generator impedances. P-type silicon with resistivity of 16,000 ohm cm and minority lifetime of 1200 μsec has been made in this way. (Bell Telephone Laboratories, Dept. S676)

■ DISTILLED-WATER TANK is equipped with built-in ultraviolet light for continuous sterilization of contents. Tanks are available in capacities from 5 to 1000 gal and in cylindrical or box form. (Barnstead Still and Sterilizer Co., Dept. S674)

■ RADIOISOTOPE-EXCITED LAMP provides illumination for marking applications for periods of 10 years or more without need for power or maintenance. The unit is 6 in. long and has a luminous diameter of 5 in. Brightness is 1000 μlam. Depending on the phosphor used, light emission may be in the blue, green, yellow, or orange regions of the spectrum. (United States Radium Corp., Dept. S679)

■ CIRCUIT BOARD for "breadboard" circuit development uses 130 conductive cells, arranged in a quadrilateral pattern. Location of the conductive cells is identified by intersections of a network of grid lines. Component leads are inserted into the cells through an elastic covering to make connections. Individual components may be replaced or reassembled without damaging leads or loosening contacts. (Van-Dee Products, Dept. S680)

■ PRESSURE STANDARD for calibration of pressure instruments attains ± 0.05 percent accuracy for full-scale ranges from 5 to 2500 lb/in.^{2} and ± 0.1 percent for ranges from 3000 to 10,000 lb/in.^{2} The unit, consisting of a pressure pickup, a frequency-modulated oscillator, and an integral power supply, is portable. (Wiancko Engineering Co., Dept. S681)

■ BALL-AND-DISK INTEGRATORS adapted to strip chart recorders provide integration against time or against chart travel. Read-out may be by visual counter with manual reset, by digital printing on the same chart, or by pips along the edge of the chart with every tenth pip in the reverse direction. (Royson Engineering Co., Dept. S692)

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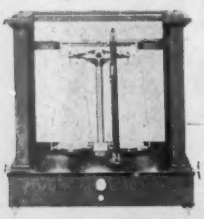

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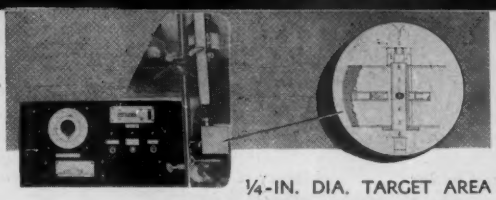

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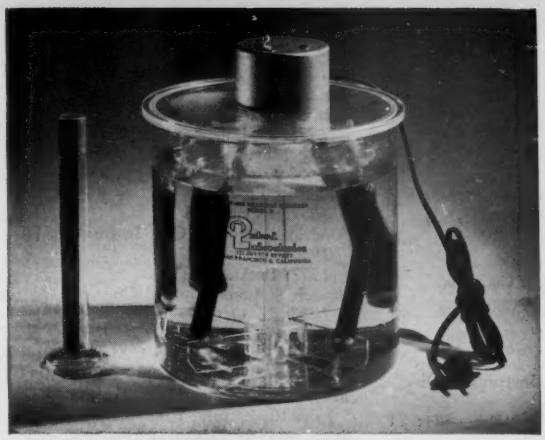
1957: 25 Jan., 140; 1 Feb., 210
Morrow, William, and Co., Inc.
1956: 26 Oct., 853
Oxford University Press, Inc.
1957: 15 Feb., 260; 26 Apr., 847; 14 June, 1213; 13 Sept., 527
Pantheon Books, Inc.
1957: 17 May, 1004
Pergamon Press
1956: 2 Nov., 907
1957: 8 Feb., 243; 15 Feb., 263; 22 Feb., 370; 3 May, 867; 17 May, 962; 24 May, 1020; 31 May, 1064; 7 June, 1120; 14 June, 1178; 21 June, 1228; 28 June, 1270; 5 July, 8; 6 Sept., 430; 13 Sept., 482; 20 Sept., 542; 27 Sept., 596; 4 Oct., 634; 11 Oct., 680; 18 Oct., 722
Philosophical Library
1956: 26 Oct., 846, 856; 7 Dec., 1169
1957: 26 Apr., 847; 7 June, 1160
Prentice-Hall, Inc.
1956: 9 Nov., 949; 14 Dec., 1227
1957: 18 Jan., 134; 8 Mar., 461; 26 Apr., 784; 11 Oct., 711
Princeton University Press
1957: 11 Jan., 84
Reichner, Herbert
1957: 29 Mar., 576
Reinhold Publishing Corp.
1957: 1 Mar., 379; 26 Apr., 836
Ronald Press Co.
1956: 26 Oct., 856; 9 Nov., 946; 16 Nov., 997
1957: 11 Jan., 81; 15 Mar., 472; 26 Apr., 834; 19 July, 134; 13 Sept., 530
Saunders, W. B., Co.
1956: 9 Nov., 911; 23 Nov., 1007; 7 Dec., 1103
1957: 4 Jan., 3; 1 Feb., 175; 1 Mar., 375; 5 Apr., 623; 12 Apr., 671; 19 Apr., 718; 26 Apr., 767; 3 May, 863; 10 May, 911; 17 May, 959; 24 May, 1015; 7 June, 1111; 5 July, 3; 2 Aug., 187; 13 Sept., 475; 11 Oct., 675
Simon and Schuster, Inc.
1957: 18 Oct., 767
Stanford University Press
1957: 26 Apr., 840



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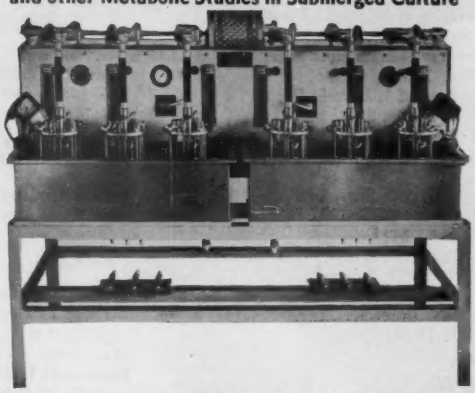

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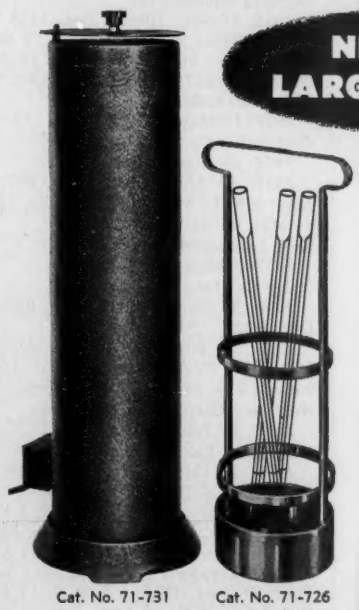

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Syracuse University Press
1956: 26 Oct., 863
University of California Press
1956: 26 Oct., 860
University of Michigan Press
1956: 26 Oct., 836
University of Minnesota Press
1956: 7 Dec., 1172
University of Wisconsin Press
1957: 5 July, 39
Van Nostrand, D., Co., Inc.
1957: 1 Mar., 412; 26 Apr., 846; 11 Oct., 679
Wiley, John, & Sons, Inc.
1956: 26 Oct., 839; 16 Nov., 991; 7 Dec., 1110–1111
1957: 11 Jan., 46; 22 Feb., 328; 15 Mar., 509; 26 Apr., 768–769; 11 Oct., 677
Year Book Publishers, Inc.
1957: 10 May, 912

BORERS

Sargent, E. H., & Co.
1956: 26 Oct., 867
1957: 14 June, 1219

BOTTLES

Ace Glass, Inc.
1957: 15 Mar., 513; 30 Aug., 419
Nalge Co., Inc.
1956: 14 Dec., 1222
1957: 18 Jan., 128; 17 May, 1006; 9 Aug., 275
Palo Laboratory Supplies, Inc.
1957: 26 Apr., 780; 4 Oct., 671
Thomas, Arthur H., Co.
1957: 12 July, 96

BURNERS

Central Scientific Co.
1956: 26 Oct., 743
1957: 11 Jan., 87

CAGES, ANIMAL

Williamson Development Co., Inc.
1957: 19 Apr., 759

CAMERAS

American Optical Co., Instrument Div.
1956: 14 Dec., 1228
1957: 18 Jan., 136; 15 Feb., 324; 24 May, 1060; 30 Aug., 424
Brinkmann Instruments, Inc.
1957: 22 Feb., 330; 15 Mar., 510
Eastman Kodak Co.
1956: 9 Nov., 947
1957: 4 Oct., 636
Polaroid Corp.
1957: 19 July, 98–99; 16 Aug., 282–283; 27 Sept., 589

CARBOYS

Nalge Co., Inc.
1956: 14 Dec., 1222
1957: 17 May, 1006; 9 Aug., 275

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CATALOGS

Ace Glass, Inc.
1957: 12 Apr., 707; 10 May, 948; 7 June, 1162
Ainsworth, Wm., & Sons, Inc.
1957: 11 Jan., 82; 8 Feb., 244; 5 Apr., 659; 3 May, 902; 28 June, 1310; 26 July, 176; 23 Aug., 368; 20 Sept., 572
Allied Radio
1957: 4 Oct., 666
American Optical Co., Instrument Div.
1956: 26 Oct., 757
1957: 16 Aug., 328
Bausch & Lomb Optical Co.
1956: 26 Oct., 772; 7 Dec., 1124; 21 Dec., 1232
1957: 15 Feb., 270; 1 Mar., 382; 15 Mar., 476; 29 Mar., 578; 3 May, 900; 10 May, 914; 7 June, 1122; 21 June, 1230; 5 July, 10; 19 July, 104; 30 Aug., 380; 13 Sept., 484; 11 Oct., 682
Beckman Instruments, Inc., Scientific Instrument Div.
1956: 26 Oct., 753
Castle, Wilmot, Co.
1957: 15 Feb., 314; 26 Apr., 842; 21 June, 1258
Clay-Adams, Inc.
1956: 21 Dec., 1266
1957: 26 Apr., 854
Coleman Instruments, Inc.
1956: 26 Oct., 840
Colorado Serum Co.
1957: 3 May, 864
Corning Glass Works
1956: 26 Oct., 763; 7 Dec., 1108
1957: 4 Jan., 2; 1 Mar., 376; 3 May, 907; 5 July, 2
Ealing Corp.
1956: 26 Oct., 768
Edmund Scientific Co.
1956: 23 Nov., 1046; 7 Dec., 1158
1957: 4 Jan., 32; 1 Feb., 204; 1 Mar., 412; 5 Apr., 660; 3 May, 896; 12 July, 89; 2 Aug., 222; 6 Sept., 466; 4 Oct., 667
Fisher Scientific Co.
1957: 17 May, 1004
Graf-Apsco Co.
1956: 16 Nov., 960
1957: 19 Apr., 759; 3 May, 897; 10 May, 946; 17 May, 1003; 24 May, 1058; 31 May, 1106; 13 Sept., 523
Kern Laboratory Supply Co.
1957: 3 May, 898; 5 July, 39
Nalge Co., Inc.
1956: 26 Oct., 843; 16 Nov., 996; 14 Dec., 1222
1957: 18 Jan., 128; 15 Feb., 310; 15 Mar., 514; 26 Apr., 844; 17 May, 1006; 9 Aug., 275; 16 Aug., 320; 20 Sept., 574
Nucleonic Corporation of America
1957: 15 Feb., 266
Nutritional Biochemicals Corp.
1956: 26 Oct., 847; 9 Nov., 949; 23 Nov., 1045; 7 Dec., 1163; 28 Dec., 1306
1957: 4 Jan., 33; 18 Jan., 129; 1 Feb., 205; 15 Feb., 311; 1 Mar., 415; 15 Mar., 510; 29 Mar., 618; 12 Apr., 674; 26 Apr., 839; 10 May, 946; 24 May, 1058; 7 June, 1118; 21 June, 1255; 5 July, 6; 19 July, 100; 2 Aug., 226; 16 Aug., 323; 30 Aug., 417; 13 Sept., 480; 27 Sept., 621; 11 Oct., 678
Olympus Optical Instrument Co.
1956: 16 Nov., 997
1957: 4 Jan., 38
Research Equipment Corp.
1956: 9 Nov., 950; 7 Dec., 1171

1957: 4 Jan., 33; 1 Feb., 210; 15 Feb., 258; 5 Apr., 661; 26 Apr., 845; 3 May, 864; 7 June, 1167

Research Specialties Co.
1956: 2 Nov., 872; 16 Nov., 994; 23 Nov., 1045; 21 Dec., 1266
1957: 15 Feb., 311; 22 Feb., 364; 1 Mar., 378; 22 Mar., 570; 29 Mar., 612; 19 Apr., 759; 3 May, 903; 10 May, 948; 17 May, 1003; 31 May, 1103; 7 June, 1118; 28 June, 1311; 5 July, 43; 12 July, 89; 13 Sept., 530

Sigma Chemical Co.
1956: 26 Oct., 853; 7 Dec., 1120; 21 Dec., 1266
1957: 25 Jan., 171; 1 Feb., 206; 8 Feb., 245; 31 May, 1106; 21 June, 1257; 19 July, 131; 16 Aug., 321; 13 Sept., 523

Stoelting, C. H., Co.
1957: 3 May, 906

Synthetical Laboratories
1956: 26 Oct., 857

Thomas, Arthur H., Co.
1957: 20 Sept., 584

Tracerlab, Inc.
1956: 26 Oct., 759
1957: 24 May, 1054; 6 Sept., 461

United Scientific Co.
1956: 30 Nov., 1095; 7 Dec., 1172; 14 Dec., 1184
1957: 15 Feb., 266; 1 Mar., 414; 29 Mar., 575; 26 Apr., 846; 24 May, 1055; 21 June, 1262; 28 June, 1309; 27 Sept., 587; 18 Oct., 760

CATHETOMETERS

Central Scientific Co.
1957: 20 Sept., 538

CENTRIFUGES AND ACCESSORIES

Beckman Instruments, Inc., Spinco Div.
1956: 26 Oct., 767; 28 Dec., 1272
1957: 11 Jan., 45; 25 Jan., 139; 15 Mar., 474; 24 May, 1059; 12 July, 51; 13 Sept., 535; 20 Sept., 541

Clay-Adams, Inc.
1956: 26 Oct., 847
1957: 1 Mar., 378; 23 Aug., 375

Custom Scientific Instruments, Inc.
1956: 26 Oct., 851

International Equipment Co.
1956: 26 Oct., 758; 16 Nov., 959; 7 Dec., 1119
1957: 18 Jan., 93; 15 Feb., 268; 1 Mar., 377; 29 Mar., 574; 26 Apr., 775; 24 May, 1014; 7 June, 1116; 19 July, 143; 27 Sept., 595

Labline, Inc.
1956: 26 Oct., 848

Lourdes Instrument Corp.
1956: 26 Oct., 762; 7 Dec., 1104
1957: 15 Feb., 267; 29 Mar., 615; 12 Apr., 708; 26 Apr., 848; 28 June, 1309; 5 July, 41; 26 July, 179; 16 Aug., 319; 13 Sept., 527; 4 Oct., 666

Nalge Co., Inc.
1956: 26 Oct., 843

Phillips-Drucker, Inc.
1956: 26 Oct., 861

Sorvall, Ivan, Inc.
1956: 26 Oct., 744–745; 23 Nov., 1006; 7 Dec., 1117
1957: 18 Jan., 135; 15 Feb., 256; 22 Mar., 526; 31 May, 1062; 21 June, 2224; 26 July, 147; 20 Sept., 539

Will Corp.
1957: 15 Feb., 317

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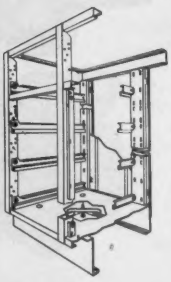

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CHEMICALS, BIOLOGICAL

Agricultural Biologicals Corp.
1957: 19 July, 137
Borden Co., Chemical Div.
1957: 1 Mar., 413; 22 Mar., 570; 19 Apr., 763; 17 May, 1007; 21 June, 1266; 20 Sept., 577; 18 Oct., 763
Clinton Laboratories
1957: 23 Aug., 367
Difco Laboratories
1957: 15 Mar., 545; 12 Apr., 714; 10 May, 951; 7 June, 1164; 5 July, 39; 2 Aug., 221; 30 Aug., 415; 13 Sept., 529; 27 Sept., 623
Eastman Kodak Co.
1957: 9 Aug., 239
Horner, Frank W., Ltd.
1957: 26 July, 179
LaMotte Chemical Products Co.
1956: 26 Oct., 855
Nutritional Biochemicals Corp.
1956: 26 Oct., 847; 9 Nov., 949; 23 Nov., 1045; 7 Dec., 1163; 28 Dec., 1306
1957: 4 Jan., 33; 18 Jan., 129; 1 Feb., 205; 15 Feb., 311; 1 Mar., 415; 15 Mar., 510; 29 Mar., 618; 12 Apr., 674; 26 Apr., 839; 10 May, 946; 24 May, 1058; 7 June, 1118; 21 June, 1255; 5 July, 6; 19 July, 100; 2 Aug., 226; 16 Aug., 323; 30 Aug., 417; 13 Sept., 480; 27 Sept., 621; 11 Oct., 678
Pfaltz & Bauer, Inc.
1956: 26 Oct., 856
Pfizer, Chas., & Co., Inc.
1956: 27 Dec., 1109
Schwarz Laboratories, Inc.
1956: 26 Oct., 841; 16 Nov., 998; 7 Dec., 1166
1957: 18 Jan., 92; 15 Feb., 318; 15 Mar., 519; 26 Apr., 852; 17 May, 1005; 21 June, 1263; 12 July, 91; 9 Aug., 272; 13 Sept., 531
Sigma Chemical Co.
1956: 26 Oct., 853; 7 Dec., 1120; 21 Dec., 1266
1957: 25 Jan., 171; 1 Feb., 206; 8 Feb., 245; 31 May, 1106; 21 June, 1257; 19 July, 131; 16 Aug., 321; 13 Sept., 523; 11 Oct., 713
Winthrop Laboratories
1956: 9 Nov., 914; 7 Dec., 1165
1957: 15 Feb., 309; 22 Mar., 567; 26 Apr., 845; 31 May, 1101; 20 Sept., 580
Worthington Biochemical Corp.
1957: 15 Feb., 315; 22 Feb., 330; 22 Mar., 570; 29 Mar., 612; 5 Apr., 667; 12 Apr., 711; 3 May, 898; 26 July, 180; 2 Aug., 225

CHEMICALS, GENERAL

Arapahoe Chemicals, Inc.
1956: 23 Nov., 1047
Bio-Basic, Inc.
1957: 13 Sept., 530
Borden Co., Chemical Div.
1957: 17 May, 1007; 18 Oct., 763
Eastman Kodak Co.
1956: 7 Dec., 1159
1957: 8 Mar., 424
Fisher Scientific Co.
1957: 12 Apr., 706; 16 Aug., 318; 13 Sept., 530
LaMotte Chemical Products Co.
1956: 26 Oct., 855
Lindsay Chemical Co.
1956: 16 Nov., 958
Lithium Corporation of America, Inc.
1956: 26 Oct., 749

1957: 11 Jan., 43; 26 Apr., 858; 14 June, 1176; 12 July, 95

CHEMICALS, ORGANIC

Eastman Kodak Co.
1957: 4 Jan., 31; 8 Feb., 216; 5 Apr., 624; 3 May, 895; 17 May, 1001; 7 June, 1159; 6 Sept., 429; 4 Oct., 636
Monsanto Chemical Co., Organic Chemicals Div.
1956: 28 Dec., 1270–1271

CHEMICALS, TRACER

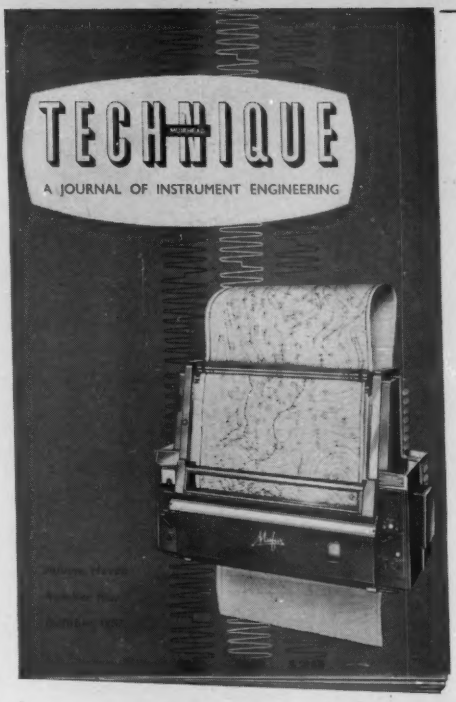
Arapahoe Chemicals, Inc.
1957: 12 Apr., 674
Isomet Corp.
1957: 8 Mar., 462
Nuclear-Chicago Corp.
1957: 3 May, 862; 17 May, 961
Research Specialties Co.
1956: 23 Nov., 1045; 28 Dec., 1274
1957: 1 Feb., 207; 29 Mar., 612; 17 May, 1003; 28 June, 1311; 19 July, 133; 9 Aug., 279
Tracerlab, Inc.
1957: 24 May, 1054; 6 Sept., 461

CHROMATOGRAPHY EQUIPMENT

Bio-Basic, Inc.
1957: 13 Sept., 530
Microchemical Specialties Co.
1956: 26 Oct., 866; 16 Nov., 1001; 7 Dec., 1177
1957: 22 Feb., 369; 22 Mar., 569; 5 Apr., 665; 21 June, 1265; 19 July, 142; 2 Aug., 229
Packard Instrument Co.
1956: 23 Nov., 1042
1957: 11 Jan., 80; 26 Apr., 838; 24 May, 1052; 14 June, 1212
Photovolt Corp.
1956: 26 Oct., 845; 16 Nov., 993; 30 Nov., 1099; 21 Dec., 1261
1957: 4 Jan., 33; 8 Feb., 245; 1 Mar., 413; 29 Mar., 612; 12 Apr., 711; 10 May, 951; 31 May, 1106; 14 June, 1211; 12 July, 94; 9 Aug., 279; 30 Aug., 417; 6 Sept., 464; 4 Oct., 665
Podbielniak, Inc.
1956: 7 Dec., 1102, 1122
Research Equipment Corp.
1956: 26 Oct., 847; 9 Nov., 950; 7 Dec., 1171
1957: 4 Jan., 33; 1 Feb., 210; 15 Feb., 258; 1 Mar., 413; 5 Apr., 661; 26 Apr., 845; 3 May, 864; 7 June, 1167
Research Specialties Co.
1956: 2 Nov., 872; 21 Dec., 1266
1957: 25 Jan., 171; 1 Mar., 378; 22 Mar., 570; 19 Apr., 759; 7 June, 1118; 23 Aug., 332; 6 Sept., 462
Schaar and Co.
1956: 2 Nov., 870
Thomas, Arthur H., Co.
1957: 12 July, 96; 4 Oct., 672
Tracerlab, Inc.
1957: 9 Aug., 235
Wilkens Instrument & Research, Inc.
1957: 19 July, 133

CLEANSERS

Alconox, Inc.
1956: 26 Oct., 836
1957: 18 Jan., 130; 22 Mar., 566; 13 Sept., 476



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Linbro Chemical Co.
1956: 26 Oct., 857; 9 Nov., 951; 7 Dec., 1118
1957: 15 Feb., 264; 26 Apr., 858
Standard Scientific Supply Corp.
1957: 15 Mar., 516
Thomas, Arthur H., Co.
1956: 9 Nov., 956

COLORIMETERS AND ACCESSORIES

Bausch & Lomb Optical Co.
1957: 7 June, 1122; 30 Aug., 380
Biddle, James G., Co.
1957: 18 Jan., 134
Fisher Scientific Co.
1957: 15 Feb., 266
Klett Manufacturing Co.
1956: 2 Nov., 872; 14 Dec., 1184
1957: 25 Jan., 140; 8 Mar., 461; 19 Apr., 756; 31 May, 1104; 12 July, 87; 23 Aug., 375; 4 Oct., 668
Photovolt Corp.
1957: 20 Sept., 577
Thomas, Arthur H., Co.
1957: 9 Aug., 280

COMPUTERS

Alwac Corp.
1957: 1 Feb., 176

CONDENSERS

Niagara Blower Co.
1957: 8 Mar., 462; 18 Oct., 760

CONSTANT TEMPERATURE CIRCULATORS

Will Corp., Bronwill Scientific Div.
1957: 26 Apr., 837; 17 May, 1004; 12 July, 90

CRUCIBLES

Corning Glass Works
1956: 26 Oct., 763

DECAPITATORS

Harvard Apparatus Co., Inc.
1957: 11 Oct., 713

DELINEASCOPES

American Optical Co., Instrument Div.
1957: 10 May, 956

DENSITOMETER

Photovolt Corp.
1956: 26 Oct., 845; 16 Nov., 993; 30 Nov., 1099; 21 Dec., 1261
1957: 4 Jan., 33; 8 Feb., 245; 1 Mar., 413; 29 Mar., 612; 12 Apr., 711; 10 May, 951; 31 May, 1106; 14 June, 1211; 12 July, 94; 9 Aug., 279; 30 Aug., 417; 6 Sept., 464; 4 Oct., 665
Welch, W. M., Manufacturing Co.
1956: 2 Nov., 872
1957: 4 Jan., 36

DESALTERS

Research Equipment Corp.
1956: 9 Nov., 950
1957: 4 Jan., 33; 15 Feb., 258; 5 Apr., 661; 26 Apr., 845
Research Specialties Co., Reco Div.
1957: 23 Aug., 332; 4 Oct., 665

DESICCANTS

Hammond, W. A., Drierite Co.
1956: 26 Oct., 864; 9 Nov., 914; 7 Dec., 1173
1957: 11 Jan., 44; 15 Feb., 258; 15 Mar., 517

DESICCATORS

Corning Glass Works
1956: 26 Oct., 763

DIALYZERS

Laboratory Glass & Instruments Corp.
1956: 26 Oct., 851
Oxford Laboratories
1957: 18 Jan., 94; 15 Feb., 262; 26 Apr., 851; 3 May, 898; 10 May, 945; 9 Aug., 274

DIFFRACTION GRATINGS

Farrand Optical Co., Inc.
1957: 12 July, 50; 13 Sept., 474

DISTILLOGRAPHS

Research Equipment Corp.
1957: 4 Jan., 33; 15 Feb., 258; 1 Mar., 413; 26 Apr., 845; 3 May, 864

DRYERS

Phipps & Bird, Inc.
1957: 24 May, 1053; 31 May, 1101
Standard Scientific Supply Corp.
1957: 25 Jan., 166

ELECTROENCEPHALOGRAPHS

Gilson Medical Electronics
1957: 14 June, 1210

ELECTROMETERS

Applied Physics Corp.
1957: 15 Feb., 260
Cambridge Instrument Co., Inc.
1956: 26 Oct., 766

ELECTROPHORESIS APPARATUS

Brinkmann Instruments, Inc.
1957: 8 Mar., 463
Beckman Instruments, Inc., Spinco Div.
1956: 9 Nov., 910; 23 Nov., 1052; 7 Dec., 1115
1957: 15 Feb., 261; 1 Mar., 419; 29 Mar., 611; 12 Apr., 670; 26 Apr., 766; 7 June, 1115; 26 July, 148; 23 Aug., 330; 11 Oct., 674
E-C Apparatus Co.
1956: 26 Oct., 850
1957: 15 Feb., 309
Harvard Apparatus Co., Inc.
1957: 12 Apr., 672
Klett Manufacturing Co.
1956: 26 Oct., 855; 2 Nov., 872; 9 Nov., 951; 16 Nov., 997; 23 Nov., 1045; 30 Nov., 1099; 7 Dec., 1163; 14 Dec., 1184; 21 Dec., 1261; 28 Dec., 1306
1957: 4 Jan., 35; 11 Jan., 86; 18 Jan., 129; 25 Jan., 140; 1 Feb., 205; 8 Feb., 246; 15 Feb., 311; 22 Feb., 367; 1 Mar., 414; 8 Mar., 461; 15 Mar., 472; 22 Mar., 567; 29 Mar., 618; 5 Apr., 667; 12 Apr., 709; 19 Apr., 756; 26 Apr., 849; 3 May, 897; 10 May, 947; 17 May, 1007; 24 May, 1018; 31 May, 1104; 7 June, 1164; 14 June, 1218; 21 June, 1266; 28 June, 1309; 5 July, 43; 12 July, 87; 19 July, 137; 2 Aug., 227; 9 Aug., 273; 16 Aug., 321; 23 Aug., 375; 30 Aug., 417; 6 Sept., 462; 13 Sept., 529; 20 Sept., 571; 11 Oct., 715; 27 Sept., 627; 18 Oct., 761
Laboratory Glass & Instruments Corp.
1956: 26 Oct., 851
Phipps & Bird, Inc.
1957: 12 July, 87; 19 July, 100
Photovolt Corp.
1956: 26 Oct., 845; 16 Nov., 993; 30 Nov., 1099; 21 Dec., 1261
1957: 4 Jan., 33; 8 Feb., 245; 1 Mar., 413; 29 Mar., 612; 12 Apr., 711; 10 May, 951; 31 May, 1106; 14 June, 1211; 12 July, 94; 9 Aug., 279; 30 Aug., 417; 6 Sept., 464; 20 Sept., 577; 4 Oct., 665; 11 Oct., 716
Research Specialties Co.
1957: 22 Feb., 364; 10 May, 948

ELLIPSOMETERS

Rudolph, O. C., & Sons
1956: 26 Oct., 861

EVAPORATORS

Instrumentation Associates
1957: 26 Apr., 836
Standard Scientific Supply Corp.
1957: 20 Sept., 576

EXTRACTORS

Aloe, A. S., Co., Aloe Scientific Div.
1957: 4 Jan., 38; 1 Feb., 207

FERMENTORS AND ACCESSORIES

New Brunswick Scientific Co.
1956: 16 Nov., 997; 14 Dec., 1227
1957: 25 Jan., 140; 15 Feb., 309; 26 Apr., 849; 23 Aug., 332

FILM

Eastman Kodak Co.
1956: 9 Nov., 947
1957: 3 May, 895; 6 Sept., 429; 4 Oct., 636
Polaroid Corp.
1957: 19 July, 98–99; 16 Aug., 282–283

FILM BADGES

Nucleonic Corporation of America
1957: 15 Feb., 266

FILTERS

Eastman Kodak Co.
1957: 3 May, 895
Standard Scientific Supply Corp.
1956: 26 Oct., 761
1957: 26 Apr., 855; 23 Aug., 371

FILTERS, INTERFERENCE

Bausch & Lomb Optical Co.
1957: 24 May, 1022; 2 Aug., 190
Farrand Optical Co., Inc.
1956: 16 Nov., 1000
1957: 15 Feb., 309; 4 Oct., 663

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Fish-Schurman Corp.
1957: 19 July, 133

FLASKS

Ace Glass, Inc.
1957: 15 Mar., 513
Corning Glass Works
1957: 6 Sept., 432
Palo Laboratory Supplies, Inc.
1957: 13 Sept., 527

FLOW TEST KIT

Ace Glass, Inc.
1957: 2 Aug., 223

FLUID DISPENSERS

Palo Laboratory Supplies, Inc.
1957: 26 Apr., 780; 4 Oct., 671

FLUOROMETERS

Coleman Instruments, Inc.
1957: 3 May, 897; 2 Aug., 226
Farrand Optical Co., Inc.
1957: 11 Jan., 44; 12 Apr., 709
Klett Manufacturing Co.
1956: 30 Nov., 1099
1957: 11 Jan., 86; 22 Feb., 367; 5 Apr., 667; 17 May, 1007; 28 June, 1309; 9 Aug., 273; 20 Sept., 571
Photovolt Corp.
1956: 26 Oct., 845; 9 Nov., 951; 23 Nov., 1043; 7 Dec., 1165; 28 Dec., 1306
1957: 11 Jan., 81; 25 Jan., 171; 22 Feb., 330; 8 Mar., 426; 5 Apr., 666; 3 May, 903; 7 June, 1170; 5 July, 43; 2 Aug., 221; 27 Sept., 620; 18 Oct., 763

FRACTIONATORS

E-C Apparatus Co.
1956: 26 Oct., 850
1957: 15 Feb., 264; 30 Aug., 416

FRACTION COLLECTORS

Aloe, A. S., Co., Aloe Scientific Div.
1956: 7 Dec., 1161
1957: 6 Sept., 428
Packard Instrument Co.
1956: 26 Oct., 837; 23 Nov., 1042; 7 Dec., 1162
1957: 11 Jan., 80; 15 Feb., 319; 26 Apr., 838; 24 May, 1052; 14 June, 1212
Research Equipment Corp.
1956: 26 Oct., 847
1957: 1 Feb., 210; 7 June, 1167
Research Specialties Co., Reco Div.
1957: 30 Aug., 415; 20 Sept., 577; 18 Oct., 761
Schaar and Co.
1956: 2 Nov., 870
1957: 18 Jan., 131

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American Instrument Co., Inc.
1957: 15 Feb., 255
Custom Scientific Instruments, Inc.
1956: 26 Oct., 851
National Research Corp., NRC Equipment Corp.
1956: 26 Oct., 833
Will Corp.
1957: 15 Feb., 317

FUNNELS

Ace Glass, Inc.
1957: 7 June, 1162
American Hospital Supply Corp., Scientific Products Div.
1957: 9 Aug., 236
Corning Glass Works
1956: 7 Dec., 1107
1957: 5 July, 2
Nalge Co., Inc.
1956: 26 Oct., 843
1957: 14 June, 1215

FURNACES

Brinkmann Instruments, Inc.
1956: 23 Nov., 1043
National Research Corp., NRC Equipment Corp.
1956: 26 Oct., 833
1957: 6 Sept., 462
Pereny Equipment Co.
1957: 22 Mar., 567; 19 Apr., 757; 17 May, 1010; 14 June, 1211; 12 July, 87; 9 Aug., 274; 6 Sept., 428; 4 Oct., 661
Thermo Electric Manufacturing Co.
1957: 15 Feb., 322

FURNACES, SOLAR ENERGY

Edmund Scientific Co.
1957: 7 June, 1166; 12 July, 89; 2 Aug., 222; 6 Sept., 466; 4 Oct., 667

FURNITURE, LABORATORY

Blickman, S.
1957: 19 Apr., 720; 21 June, 1226; 18 Oct., 759
Brinkmann, C. A., & Co.
1957: 22 Mar., 565
Fisher Scientific Co.
1957: 17 May, 1004; 4 Oct., 667
New Brunswick Scientific Co.
1957: 24 May, 1053; 27 Sept., 623
Research Specialties Co.
1957: 8 Feb., 246; 12 Apr., 706; 14 June, 1218
Standard Scientific Supply Corp.
1957: 17 May, 1002
Technicon Co.
1956: 26 Oct., 845; 16 Nov., 993; 7 Dec., 1120; 28 Dec., 1274
1957: 18 Jan., 94; 15 Feb., 307; 15 Mar., 522; 12 Apr., 674; 10 May, 951

GAS-ANALYSIS APPARATUS

National Research Corp., NRC Equipment Div.
1956: 26 Oct., 833
Perkin-Elmer Corp.
1956: 26 Oct., 770

GAUGES

Ace Glass, Inc.
1957: 5 July, 41

GENERATORS

Edmund Scientific Corp.
1956: 26 Oct., 842; 23 Nov., 1046; 7 Dec., 1158
1957: 4 Jan., 32

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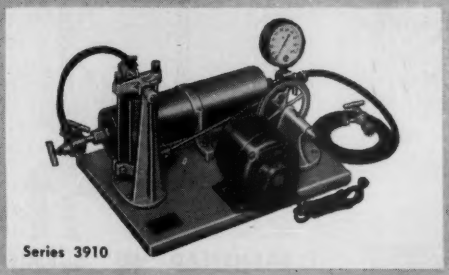

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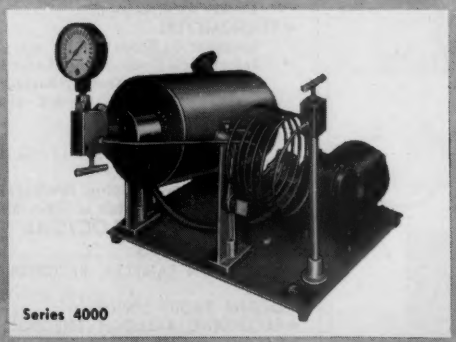

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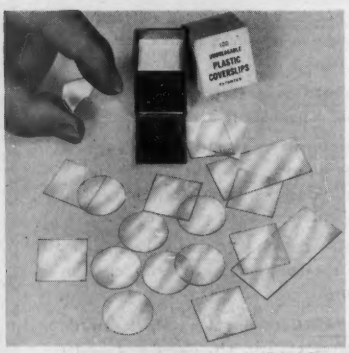

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General Ultrasonics Co.
1956: 26 Oct., 746
Philips Electronics, Inc., Instruments Div.
1957: 20 Sept., 583

GLASSWARE AND ACCESSORIES

Ace Glass, Inc.
1957: 15 Feb., 313; 10 May, 948; 7 June, 1162; 27 Sept., 624
Corning Glass Works
1956: 26 Oct., 763; 7 Dec., 1108
1957: 4 Jan., 2; 1 Mar., 376; 3 May, 907; 5 July, 2; 6 Sept., 432
Fisher Scientific Co.
1956: 26 Oct., 835
Kern Laboratory Supply Co.
1957: 3 May, 898; 5 July, 39
Klett Manufacturing Co.
1956: 2 Nov., 872; 16 Nov., 997; 30 Nov., 1099; 14 Dec., 1184; 28 Dec., 1306
1957: 11 Jan., 86; 25 Jan., 140; 8 Feb., 247; 22 Feb., 367; 8 Mar., 461; 22 Mar., 567; 5 Apr., 667; 19 Apr., 756; 3 May, 897; 17 May, 1007; 31 May, 1104; 14 June, 1218; 28 June, 1309; 12 July, 87; 26 July, 177; 9 Aug., 273; 23 Aug., 375; 6 Sept., 462; 20 Sept., 571; 4 Oct., 668; 18 Oct., 761
Kontes Glass Co.
1956: 26 Oct., 748
Palo Laboratory Supplies, Inc.
1957: 26 Apr., 780; 4 Oct., 671
Research Specialties Co.
1956: 2 Nov., 872; 21 Dec., 1266
1957: 25 Jan., 171; 1 Mar., 378; 22 Mar., 570; 7 June, 1118
Scientific Glass Apparatus Co., Inc.
1957: 6 Sept., 465
Standard Scientific Supply Corp.
1957: 19 July, 132
Thomas, Arthur H., Co.
1957: 20 Sept., 584

GRADUATES

Corning Glass Works
1957: 3 May, 907
Nalge Co., Inc.
1957: 15 Feb., 310; 26 Apr., 844

GREASES

Biddle, James G., Co.
1956: 14 Dec., 1227
1957: 8 Mar., 461; 13 Sept., 524

HEATERS

Biochemical Associates
1956: 26 Oct., 863
Fisher Scientific Co.
1956: 26 Oct., 835
Research Specialties Co.
1957: 15 Feb., 311; 3 May, 903; 5 July, 43
Thermo Electric Manufacturing Co.
1957: 26 Apr., 840; 11 Oct., 710

HOT PLATES

Research Specialties Co.
1957: 15 Feb., 311; 3 May, 903; 5 July, 43
Thermo Electric Manufacturing Co.
1957: 29 Mar., 610; 21 June, 1262; 13 Sept., 526

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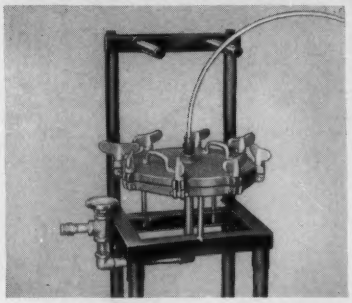

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HUMIDITY CONTROLLERS

Niagara Blower Co.
1957: 11 Jan., 83; 3 May, 900; 28 June, 1312; 23 Aug., 369

ILLUMINATORS

American Optical Co., Instrument Div.
1957: 1 Feb., 212; 12 Apr., 716; 13 Sept., 536
Bausch & Lomb Optical Co.
1956: 7 Dec., 1124; 21 Dec., 1232
1957: 10 May, 914
Beeber, J., Co., Inc.
1957: 15 Feb., 322

INCUBATORS

Central Scientific Co.
1956: 16 Nov., 961
1957: 26 July, 184
New Brunswick Scientific Co.
1957: 10 May, 945

KJELDAHL APPARATUS

Thomas, Arthur H., Co.
1957: 3 May, 908

KYMOGRAPHS

Harvard Apparatus Co., Inc.
1957: 12 Apr., 672
Phipps & Bird, Inc.
1957: 22 Feb., 365; 14 June, 1211; 21 June, 1259; 19 July, 131; 26 July, 183; 6 Sept., 471; 13 Sept., 524; 20 Sept., 575; 27 Sept., 621

LABORATORY GLAND

Smith, Arthur F., Co.
1957: 27 Sept., 593

LABORATORY JACK

Central Scientific Co.
1956: 26 Oct., 742

LABORATORY MILL

Thomas, Arthur H., Co.
1957: 8 Feb., 252

LABORATORY PRESS

Carver, Fred S., Inc.
1956: 7 Dec., 1171

LABORATORY SUPPLIES

Ace Glass, Inc.
1957: 15 Feb., 313; 27 Sept., 624
Clay-Adams, Inc.
1956: 30 Nov., 1056
1957: 15 Feb., 312; 26 July, 177
Fisher Scientific Co.
1957: 14 June, 1213; 19 July, 134; 16 Aug., 318
Lennard, P. M., Co., Inc.
1956: 26 Oct., 860
Schaar & Co.
1957: 20 Sept., 573
Standard Scientific Supply Corp.
1957: 15 Feb., 308
Thomas, Arthur H., Co.
1956: 26 Oct., 868; 7 Dec., 1180
1957: 11 Jan., 88

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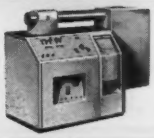

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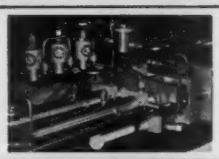

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Ace Glass, Inc.
1957: 15 Mar., 513; 30 Aug., 419
American Hospital Supply Corp., Scientific Products Div.
1957: 9 Aug., 236
Linbro Chemical Co., Inc.
1956: 26 Oct., 766; 9 Nov., 912
1957: 11 Jan., 86; 24 May, 1018
Nalge Co., Inc.
1956: 26 Oct., 843; 14 Dec., 1222
1957: 18 Jan., 128; 26 Apr., 844; 17 May, 1006; 14 June, 1215; 19 July, 136; 9 Aug., 275; 20 Sept., 574
Palo Laboratory Supplies, Inc.
1957: 13 Sept., 527
Scientific Glass Apparatus Co., Inc.
1957: 14 June, 1175
Standard Scientific Supply Corp.
1957: 26 Apr., 850

LIGHT ADAPTER

American Speedlight Corp.
1957: 5 Apr., 662; 17 May, 1000; 21 June, 1261; 26 July, 178

MACROSCOPES

Bausch & Lomb Optical Co.
1956: 26 Oct., 772; 9 Nov., 918; 23 Nov., 1010
1957: 26 Apr., 786; 6 Sept., 461

MANOMETERS

Will Corp., Bronwill Scientific Div.
1957: 3 May, 899; 7 June, 1165

MERCURY VAPOR DETECTOR

Kruger, Harold, Instruments
1957: 7 June, 1162; 6 Sept., 466

METEOROLOGICAL INSTRUMENTS

Kahl Scientific Instrument Corp.
1957: 11 Oct., 710

MICROANALYSIS EQUIPMENT

Aloe, A. S., Co., Aloe Scientific Div.
1957: 5 Apr., 667; 3 May, 866; 2 Aug., 221
Micro-Metric Instrument Co.
1956: 7 Dec., 1118
1957: 15 Feb., 264; 12 Apr., 714; 9 Aug., 273; 13 Sept., 524
Synthetical Laboratories
1956: 26 Oct., 857
Thomas, Arthur H., Co.
1957: 5 Apr., 668

MICROBIOLOGICAL EQUIPMENT

Bellco Glass, Inc.
1957: 17 May, 1012
Biological Institute
1957: 15 Feb., 264
Blickman, S., Inc.
1957: 19 Apr., 720; 21 June, 1226; 18 Oct., 759
Brinkmann Instruments, Inc.
1957: 18 Jan., 131; 15 Feb., 312
Kontes Glass Co.
1956: 26 Oct., 748
Linbro Chemical Co., Inc.
1956: 9 Nov., 912
1957: 11 Jan., 86; 24 May, 1018
New Brunswick Scientific Co.
1957: 24 May, 1053; 27 Sept., 623
Standard Scientific Supply Corp.
1957: 26 Apr., 850
Thomas, Arthur H., Co.
1957: 3 May, 908
Worthington Biochemical Corp.
1956: 26 Oct., 769; 9 Nov., 916; 23 Nov., 1051; 7 Dec., 1106; 21 Dec., 1230
1957: 4 Jan., 4; 18 Jan., 96

MICROBIOLOGICAL MEDIA

American Hospital Supply Corp., Scientific Products Div.
1957: 15 Feb., 259
Colorado Serum Co.
1957: 3 May, 864
Difco Laboratories
1956: 26 Oct., 851; 23 Nov., 1043; 21 Dec., 1261
1957: 18 Jan., 94; 15 Feb., 307; 15 Mar., 515; 12 Apr., 714; 10 May, 951; 7 June, 1164; 5 July, 39; 2 Aug., 221; 30 Aug., 415; 13 Sept., 529; 27 Sept., 623
Hyland Laboratories
1957: 18 Jan., 127; 15 Mar., 511; 10 May, 949; 13 Sept., 525

MICROMANIPULATORS

Aloe, A. S., Co., Aloe Scientific Div.
1957: 5 Apr., 667; 3 May, 866; 2 Aug., 221
American Optical Co., Instrument Div.
1957: 19 July, 144
Brinkmann Instruments, Inc.
1956: 16 Nov., 960
1957: 20 Sept., 571
Leitz, E., Inc.
1956: 9 Nov., 913; 21 Dec., 1268
1957: 1 Feb., 174; 29 Mar., 619; 10 May, 910; 5 July, 47; 13 Sept., 477

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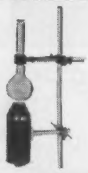

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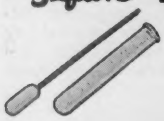

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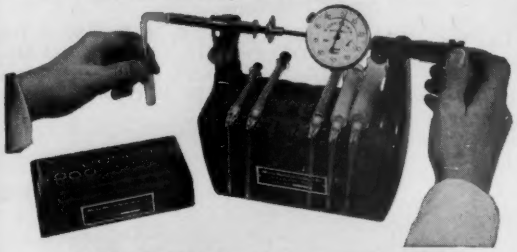

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Stoelting, C. H., Co.
1957: 19 Apr., 763; 31 May, 1101; 7 June, 1164
Will Corp.
1956: 26 Oct., 849

MICROPRINT READERS

Eastman Kodak Co.
1957: 4 Jan., 31

MICRORADIOGRAPHIC EQUIPMENT

Philips Electronics, Inc., Instruments Div.
1957: 6 Sept., 427; 20 Sept., 583; 11 Oct., 719

MICROSCOPE ACCESSORIES

American Optical Co., Instrument Div.
1957: 1 Feb., 212; 12 Apr., 716; 21 June, 1268; 13 Sept., 536
Bausch & Lomb Optical Co.
1956: 7 Dec., 1124; 21 Dec., 1232
1957: 10 May, 914
Beeber, J., Co., Inc.
1957: 15 Feb., 322
Hacker, William J., & Co., Inc.
1957: 24 May, 1017
Leitz, E., Inc.
1956: 26 Oct., 751; 23 Nov., 1008
1957: 4 Jan., 5; 18 Jan., 91; 1 Mar., 380; 15 Mar., 471; 12 Apr., 673; 26 Apr., 771; 7 June, 1113; 19 July, 101

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MICROSCOPES

American Optical Co., Instrument Div.
1956: 26 Oct., 757; 16 Nov., 1004; 28 Dec., 1308
1957: 4 Jan., 40; 1 Mar., 420; 29 Mar., 620; 26 Apr., 860; 7 June, 1172; 2 Aug., 232; 27 Sept., 632
Bausch & Lomb Optical Co.
1956: 26 Oct., 772
1957: 4 Jan., 8; 18 Jan., 98; 1 Feb., 178; 15 Feb., 270; 1 Mar., 382; 15 Mar., 476; 21 June, 1230; 19 July, 104; 6 Sept., 461; 27 Sept., 598; 4 Oct., 667
Ealing Corp.
1956: 23 Nov., 1047
Graf-Apsco Co.
1956: 16 Nov., 960
1957: 22 Feb., 365; 17 May, 1003; 27 Sept., 620
Hacker, William J., & Co., Inc.
1957: 24 May, 1017
Leitz, E., Inc.
1957: 24 May, 1019; 21 June, 1225; 2 Aug., 188; 16 Aug., 284; 30 Aug., 423; 27 Sept., 588; 11 Oct., 676
Monroe Microscope Service
1957: 27 Sept., 624
Olympus Optical Instrument Co.
1956: 26 Oct., 760; 16 Nov., 997; 7 Dec., 1121
1957: 4 Jan., 38; 15 Feb., 258
United Scientific Co.
1957: 15 Feb., 266; 24 May, 1055; 27 Sept., 587; 18 Oct., 760
Wild Heerbrugg Instruments, Inc.
1956: 26 Oct., 842
1957: 15 Feb., 316; 3 May, 901; 31 May, 1103; 21 June, 1260; 19 July, 135; 23 Aug., 370; 6 Sept., 467; 20 Sept., 579
Zeiss, Carl, Inc.
1956: 26 Oct., 765; 7 Dec., 1114
1957: 26 Apr., 781; 26 July, 150; 6 Sept., 426

MICROSCOPES, ELECTRON

Erb & Gray Scientific
1957: 12 Apr., 711; 23 Aug., 367; 11 Oct., 678
Philips Electronics, Inc., Instruments Div.
1957: 6 Sept., 427

MICROSCOPES, FLUORESCENCE

Hacker, William J., & Co., Inc.
1957: 9 Aug., 273; 20 Sept., 575
Zeiss, Carl, Inc.
1956: 16 Nov., 962
1957: 31 May, 1108

MICROSCOPES, INTERFERENCE

American Optical Co., Instrument Div.
1957: 16 Aug., 328

MICROSCOPES, PHASE

American Optical Co., Instrument Div.
1957: 5 July, 48; 11 Oct., 720
United Scientific Co.
1956: 26 Oct., 747; 7 Dec., 1113
1957: 1 Mar., 414; 29 Mar., 575; 26 Apr., 846; 24 May, 1055; 21 June, 1262

MICROSCOPES, STEREO

American Optical Co., Instrument Div.
1956: 2 Nov., 908; 30 Nov., 1100; 28 Dec., 1308
1957: 4 Jan., 40; 15 Mar., 524; 29

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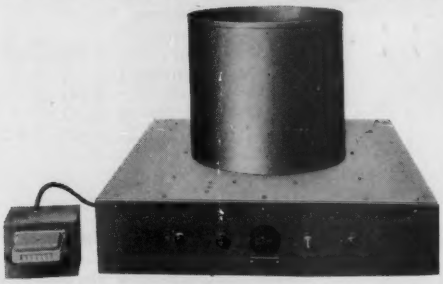

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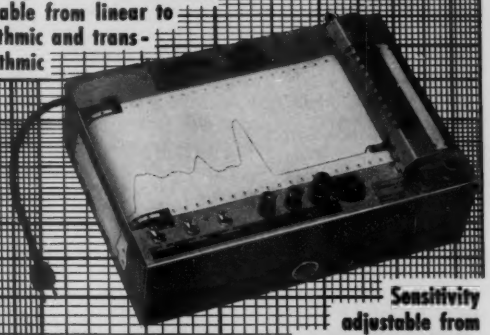

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Mar., 620; 26 Apr., 860; 7 June, 1172; 2 Aug., 232; 27 Sept., 632
Bausch & Lomb Optical Co.
1957: 12 Apr., 678; 26 Apr., 786; 16 Aug., 286
Edmund Scientific Co.
1957: 4 Jan., 32; 1 Feb., 204; 1 Mar., 412; 5 Apr., 660; 3 May, 896; 7 June, 1166; 12 July, 89; 2 Aug., 222; 6 Sept., 466; 4 Oct., 667
United Scientific Co.
1956: 26 Oct., 747; 7 Dec., 1113
1957: 29 Mar., 575

MICROSCOPES, STUDENT

Edmund Scientific Corp.
1956: 26 Oct., 842; 23 Nov., 1046; 7 Dec., 1158
1957: 5 Apr., 660; 3 May, 896
Graf-Apsco Co.
1957: 1 Feb., 207; 8 Mar., 463; 22 Mar., 570; 5 Apr., 663; 19 Apr., 759; 3 May, 897; 10 May, 946; 24 May, 1058; 31 May, 1106; 13 Sept., 523; 4 Oct., 661
Leitz, E., Inc.
1956: 7 Dec., 1105
1957: 15 Feb., 257; 2 Aug., 188; 16 Aug., 284; 30 Aug., 423
Olympus Optical Instrument Co.
1956: 26 Oct., 760

MICROTOMES AND ACCESSORIES

Aloe, A. S., Co., Aloe Scientific Div.
1957: 1 Mar., 378; 7 June, 1167; 5 July, 46; 4 Oct., 660
Brinkmann, C. A., & Co., Inc.
1957: 8 Feb., 245; 6 Sept., 471
Erb & Gray Scientific
1957: 30 Aug., 415; 18 Oct., 761
Monroe Microscope Service
1957: 27 Sept., 624
Research Specialties Co.
1956: 26 Oct., 857; 30 Nov., 1099
1957: 4 Jan., 35; 8 Mar., 426; 26 Apr., 854; 21 June, 1257
Sorvall, Ivan, Inc.
1956: 26 Oct., 844; 7 Dec., 1117
1957: 26 Apr., 858; 23 Aug., 375

MIXERS

Fisher Scientific Co.
1957: 19 July, 134
Lourdes Instrument Corp.
1956: 26 Oct., 762
Sorvall, Ivan, Inc.
1956: 7 Dec., 1117
1957: 15 Feb., 256; 21 June, 1224

MOISTURE DETERMINATORS

Central Scientific Co.
1956: 26 Oct., 742
1957: 8 Mar., 467

MONOCHROMATORS

Bausch & Lomb Optical Co.
1957: 10 May, 914; 5 July, 10; 13 Sept., 484
Farrand Optical Co., Inc.
1957: 15 Mar., 522; 7 June, 1118
Photovolt Corp.
1956: 14 Dec., 1184
1957: 1 Feb., 205; 15 Mar., 517; 26 Apr., 851; 24 May, 1053; 28 June, 1309; 26 July, 179; 23 Aug., 332

NEPHELOMETERS

Coleman Instruments, Inc.
1956: 23 Nov., 1044
1957: 12 Apr., 707; 27 Sept., 625
Klett Manufacturing Co.
1956: 16 Nov., 997; 28 Dec., 1306
1957: 8 Feb., 247; 22 Mar., 567; 3 May, 897; 14 June, 1218; 26 July, 177; 6 Sept., 462; 18 Oct., 761

NITROGEN ANALYZER

Aloe, A. S., Co., Aloe Scientific Div.
1956: 26 Oct., 768
Custom Engineering & Development Co.
1956: 26 Oct., 863

OILS

Biddle, James G., Co.
1956: 14 Dec., 1227
1957: 8 Mar., 461; 13 Sept., 524

OPTICAL CRYSTALS

Isomet Corp.
1957: 26 Apr., 839

OSCILLOSCOPES

American Electronic Laboratories
1957: 6 Sept., 466
Hickok Electrical Instrument Co.
1957: 13 Sept., 523
Hughes Products
1957: 3 May, 865; 5 July, 5
Sanborn Co.
1957: 15 Mar. 473; 12 Apr., 676; 5 July, 7; 2 Aug., 186; 30 Aug., 378; 27 Sept., 592
Stoelting, C. H., Co.
1957: 6 Sept., 464; 20 Sept., 578; 4 Oct., 665

OVENS

Central Scientific Co.
1956: 26 Oct., 743
1957: 5 Apr., 622
Research Equipment Corp.
1956: 7 Dec., 1171
Schaar and Co.
1957: 19 Apr., 763
Thomas, Arthur H., Co.
1957: 14 June, 1220

PERIODIC CHART OF THE ATOMS

Welch, W. M., Manufacturing Co.
1957: 5 Apr., 661; 26 July, 183

PETRI DISHES

Standard Scientific Supply Corp.
1957: 26 Apr., 850; 14 June, 1175

*p*H INDICATORS

Cambridge Instrument Co., Inc.
1957: 15 Feb., 315
Eastman Kodak Co.
1957: 8 Feb., 216

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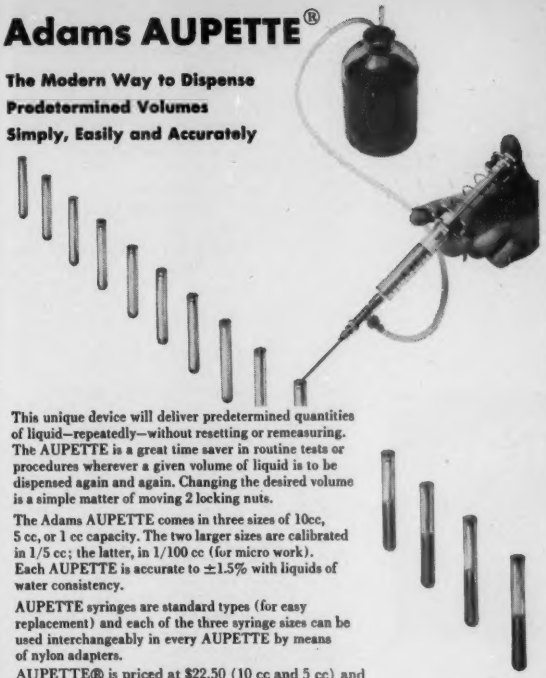

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1957: 6 Sept., 464; 20 Sept., 577; 11 Oct., 716
Polorad Electronics Corp., Scientific Instruments Div.
1956: 26 Oct., 750; 16 Nov., 1003
1957: 7 June, 1161
Scientific Glass Apparatus Co., Inc.
1957: 25 Jan., 172; 22 Feb., 366

PHOTOGRAPHIC EQUIPMENT

Eastman Kodak Co.
1956: 7 Dec., 1159
1957: 8 Mar., 424; 3 May, 895; 7 June, 1159
Polaroid Corp.
1957: 19 July, 98–99; 16 Aug., 282–283; 27 Sept., 589

PHOTOMACROGRAPHIC EQUIPMENT

American Optical Co., Instrument Div.
1956: 14 Dec., 1228
1957: 18 Jan., 136; 15 Feb., 324; 24 May, 1060; 30 Aug., 424
American Speedlight Corp.
1957: 5 Apr., 662; 17 May, 1000; 21 June, 1261; 26 July, 178
Will Corp.
1957: 26 Apr., 841

PHOTOMETERS

Biddle, James G., Co.
1957: 10 May, 947
Farrand Optical Co., Inc.
1957: 10 May, 945; 9 Aug., 279
Fisher Scientific Co.
1957: 18 Jan., 130; 15 Mar., 518
Jarrell-Ash Co.
1956: 26 Oct., 764
Kahl Scientific Instrument Corp.
1957: 11 Oct., 710
Standard Scientific Supply Corp.
1956: 30 Nov., 1054

PHOTOMETERS, EXPOSURE

Brinkmann Instruments, Inc.
1956: 30 Nov., 1056
1957: 17 May, 1010
Photovolt Corp.
1956: 2 Nov., 870
1957: 18 Jan., 129; 15 Feb., 307; 22 Mar., 567; 19 Apr., 759; 17 May, 1007; 21 June, 1259; 19 July, 137; 16 Aug., 323; 13 Sept., 529

PHOTOMICROGRAPHIC EQUIPMENT

American Optical Co., Instrument Div.
1956: 14 Dec., 1228
1957: 18 Jan., 136; 15 Feb., 324; 24 May, 1060; 30 Aug., 424
American Speedlight Corp.
1957: 5 Apr., 662; 17 May, 1000; 21 June, 1261; 26 July, 178
Bausch & Lomb Optical Co.
1957: 29 Mar., 578; 26 Apr., 786; 3 May, 900; 10 May, 914; 4 Oct., 667; 11 Oct., 682
Brinkmann Instruments, Inc.
1956: 30 Nov., 1056
1957: 22 Feb., 330; 15 Mar., 510; 17 May, 1010
Leitz, E., Inc.
1957: 27 Sept., 588; 11 Oct., 676
Photovolt Corp.
1956: 2 Nov., 870
1957: 18 Jan., 129; 15 Feb., 307; 22 Mar., 567; 19 Apr., 759; 17 May, 1007; 21 June, 1259; 19 July, 137; 16 Aug., 323; 13 Sept., 529
United Scientific Co.
1956: 26 Oct., 747; 7 Dec., 1113
1957: 29 Mar., 575; 27 Sept., 587
Will Corp.
1957: 26 Apr., 841
Zeiss, Carl, Inc.
1956: 7 Dec., 1114
1957: 4 Jan., 39; 26 July, 150; 6 Sept., 426

PIPE HEATERS

Standard Scientific Supply Corp.
1957: 29 Mar., 613

PIPETTES AND ACCESSORIES

Brinkmann Instruments, Inc.
1956: 16 Nov., 960
Clay-Adams, Inc.
1957: 25 Jan., 140; 24 May, 1018
Corning Glass Works
1957: 6 Sept., 432
Delmar Scientific Laboratories
1957: 18 Jan., 134; 15 Feb., 315; 19 Apr., 757

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References:

Proceeding of the Chemical Society (London) 1957 — Page 23

Naturwissenschaften 1957 — Page 9 — 44

Chromatographic Methods 1957 — Page 1, No. 1 — 2

For details write for descriptive Bulletin 5060.

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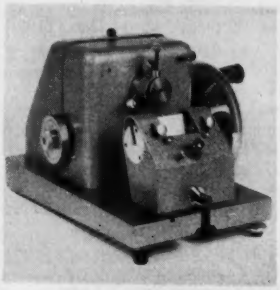

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Instrumentation Associates
1957: 26 Apr., 840
Microchemical Specialties Co.
1956: 2 Nov., 905; 21 Dec., 1265
1957: 8 Mar., 465; 19 Apr., 761; 24 May, 1057; 5 July, 45; 16 Aug., 325
Nalge Co., Inc.
1956: 26 Oct., 843
1957: 16 Aug., 320; 20 Sept., 574
Phipps & Bird, Inc.
1957: 24 May, 1053; 31 May, 1101
Research Specialties Co.
1956: 16 Nov., 994; 14 Dec., 1184
1957: 18 Jan., 92; 15 Mar., 512; 31 May, 1103; 12 July, 89; 13 Sept., 530
Standard Scientific Supply Corp.
1957: 19 July, 132
Thomas, Arthur H., Co.
1957: 15 Feb., 254; 8 Mar., 468

POLARIMETERS

Fish-Schurman Corp.
1956: 26 Oct., 766; 7 Dec., 1165
1957: 15 Feb., 262; 26 Apr., 854
Rudolph, O. C., & Sons
1956: 26 Oct., 861
Zeiss, Carl, Inc.
1957: 22 Mar., 571

POLAROGRAPHS

Sargent, E. H., & Co.
1957: 26 Apr., 782

POTENTIOMETERS

Sargent, E. H., & Co.
1957: 17 May, 958
Varian Associates, Instrument Div.
1957: 27 Sept., 590

POWER PACKS

Electronic Measurements Co., Inc.
1957: 27 Sept., 625

PROJECTORS

American Optical Co., Instrument Div.
1957: 10 May, 956
Bausch & Lomb Optical Co.
1956: 26 Oct., 772
1957: 29 Mar., 578; 3 May, 900; 6 Sept., 461; 4 Oct., 667; 11 Oct., 682
Eastman Kodak Co.
1957: 6 Sept., 429
Stoelting, C. H., Co.
1957: 17 May, 1007
Zeiss, Carl, Inc.
1957: 4 Jan., 39; 28 June, 1316

PSYCHROMETERS

Central Scientific Co.
1957: 8 Feb., 215

PUMP PLATE

Central Scientific Co.
1957: 7 June, 1119

PUMPS

Biddle, James G., Co.
1957: 8 Feb., 247; 12 July, 94
Central Scientific Co.
1956: 26 Oct., 742; 14 Dec., 1182
1957: 19 Apr., face 740
Harvard Apparatus Co., Inc.
1957: 12 Apr., 672; 20 Sept., 578
National Research Corp., NRC Equipment Div.
1956: 26 Oct., 832
1957: 22 Feb., 367; 6 Sept., 462
Phipps & Bird, Inc.
1957: 7 June, 1170; 14 June, 1214; 11 Oct., 715
Smith, Arthur F., Co.
1957: 27 Sept., 593
Standard Scientific Supply Corp.
1956: 9 Nov., 915
Welch, W. M., Manufacturing Co.
1957: 1 Mar., 415; 2 Aug., 227

PYROMETERS

Thermo Electric Manufacturing Co.
1957: 24 May, 1055; 16 Aug., 319

RADIATION COUNTERS

Biddle, James G., Co.
1957: 18 Jan., 134; 10 May, 947
Borg-Warner Corp.; BJ Electronics
1957: 18 Oct., 763
Cambridge Instrument Co., Inc.
1956: 26 Oct., 766
Nuclear Corporation of America, Inc.,
NRD Instrument Co.
1957: 21 June, 1227
Nuclear Instrument and Chemical Corp.
1956: 26 Oct., 755

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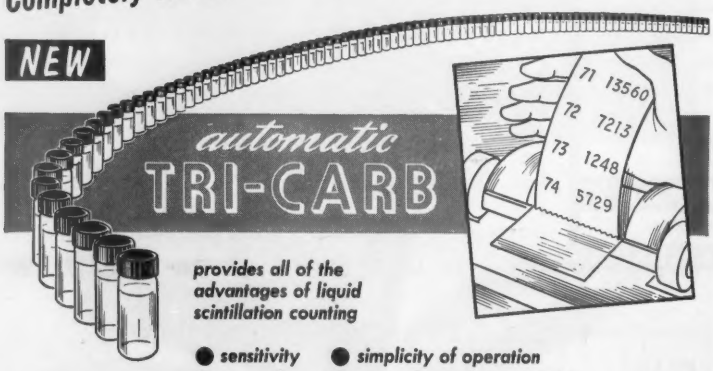

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1957: 25 Jan., 165: 19 Apr., insert; 27 Sept., 586
Packard Instrument Co.
1956: 26 Oct., 837; 7 Dec., 1162
1957: 15 Feb., 319; 10 May, 948; 7 June, 1158
Philips Electronics, Inc., Instruments Div.
1957: 11 Oct., 719
Tracerlab, Inc.
1957: 25 Jan., 138; 22 Feb., 371; 19 Apr., 764; 17 May, 1011; 12 July, 52: 9 Aug., 235; 6 Sept., 472

RADIATION RESEARCH EQUIPMENT

Blickman, S., Inc.
1957: 15 Feb., 323
Borg-Warner Corp., BJ Electronics
1957: 18 Oct., 763
Nuclear-Chicago Corp.
1957: 19 Apr., insert
Packard Instrument Co.
1957: 10 May, 948
Tracerlab, Inc.
1957: 22 Mar., 530; 17 May, 1011

RARE EARTHS

Lindsay Chemical Co.
1957: 18 Jan., 90; 15 Mar., 523; 26 Apr., 778; 17 May, 960; 19 July, 102; 20 Sept., 540

RECORDERS, GRAPHIC

Moseley, F. L., Co.
1957: 12 Apr., 710
Photovolt Corp.
1957: 20 Sept., 577; 11 Oct., 716
Sargent, E. H., & Co.
1957: 26 Apr., 782; 17 May, 958
Stoelting, C. H., Co.
1957: 3 May, 906; 21 June, 1255; 6 Sept., 464; 20 Sept., 578; 4 Oct., 665
Varian Associates, Special Products Div.
1956: 30 Nov., 1095; 14 Dec., 1224
1957: 7 June, 1117; 5 July, 4; 27 Sept., 590

RECORDING EQUIPMENT, BIOPHYSICAL

American Electronic Laboratories, Inc.
1957: 6 Sept., 466; 13 Sept., 480
American Hospital Supply Corp., Scientific Products Div.
1956: 26 Oct., 756
Gilson Medical Electronics
1957: 14 June, 1210
Phipps & Bird, Inc.
1957: 26 Apr., 051; 3 May, 903
Sanborn Co.
1957: 15 Mar., 473; 12 Apr., 676; 10 May, 955; 7 June, 1114; 5 July, 7; 2 Aug., 186; 30 Aug., 378; 27 Sept., 592
Yellow Springs Instrument Co., Inc.
1956: 26 Oct., 840
1957: 15 Feb., 306

REFRACTORS

Laszlo, S. E.
1957: 18 Jan., 92; 15 Feb., 322

RHEOSTATS

Biddle, James G., Co.
1957: 12 Apr., 714

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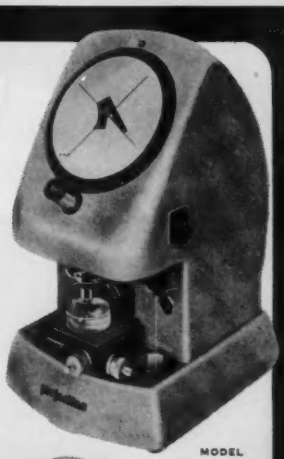

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ROTATORS

Clay-Adams, Inc.
1957: 5 Apr., 666; 28 June, 1313; 20 Sept., 571

SCALES

Welch, W. M., Manufacturing Co.
1957: 5 July, 6

SHAKERS

Blue M Electric Co.
1957: 10 May, 950

Central Scientific Co.
1956: 26 Oct., 742

Clay-Adams, Inc.
1957: 5 Apr., 666; 28 June, 1313; 20 Sept., 571

Eberbach Corp.
1956: 2 Nov., 870; 16 Nov., 960

Fisher Scientific Co.
1957: 19 July, 134

New Brunswick Scientific Co.
1956: 26 Oct., 853; 30 Nov., 1056; 28 Dec., 1274
1957: 11 Jan., 44; 22 Feb., 367; 8 Mar., 426; 12 Apr., 714; 10 May, 945; 7 June, 1161; 21 June, 1266; 13 Sept., 532; 11 Oct., 678

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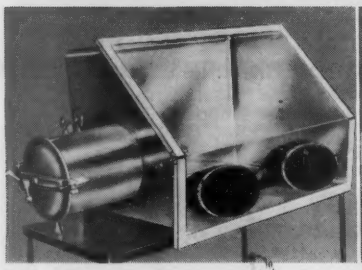

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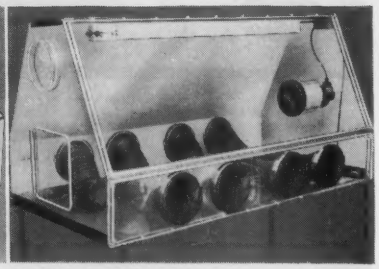

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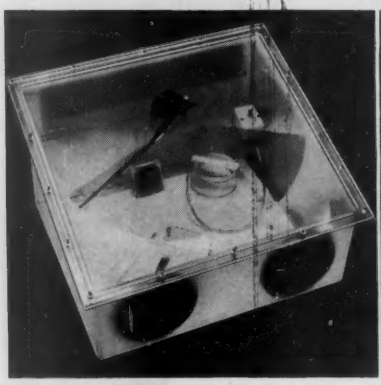

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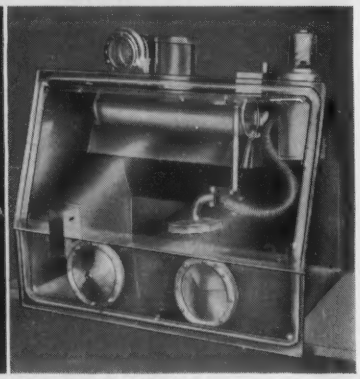

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Research Specialties Co.
1956: 9 Nov., 914; 7 Dec., 1161
1957: 11 Jan., 81; 5 Apr., 663; 24 May, 1058; 26 July, 177; 2 Aug., 225; 16 Aug., 323

Schaar and Co.
1957: 4 Oct., 661

Standard Scientific Supply Corp.
1957: 25 Jan., 166

SKELETON, MODEL

Welch, W. M., Manufacturing Co.
1956: 7 Dec., 1118
1957: 7 June, 1161; 4 Oct., 663

SPECTROMETERS

Biddle, James G., Co.
1957: 18 Jan., 134

Ealing Corp.
1956: 26 Oct., 768

Farrand Optical Co., Inc.
1957: 7 June, 1118

Jarrell-Ash Co.
1956: 26 Oct., 764

Kahl Scientific Instrument Corp.
1957: 11 Oct., 710

Nuclear Instrument and Chemical Corp.
1956: 26 Oct., 755
1957: 22 Mar., 527

Packard Instrument Co.
1956: 26 Oct., 837; 7 Dec., 1162
1957: 15 Feb., 319; 15 Mar., 513; 10 May, 948; 7 June, 1158; 27 Sept., 624

Perkin-Elmer Corp., Instrument Div.
1957: 22 Mar., 572

Tracerlab, Inc.
1956: 26 Oct., 759
1957: 14 June, 1177

Varian Associates, Instrument Div.
1956: 28 Dec., 1307
1957: 25 Jan., 142; 22 Feb., 327; 22 Mar., 528; 12 Apr., 675; 24 May, 1016; 21 June, 1267; 26 July, 146; 16 Aug., 327; 27 Sept., 631

SPECTROPHOTOMETERS AND ACCESSORIES

Applied Physics Corp.
1957: 15 Feb., 260

Beckman Instruments, Inc., Scientific Instrument Div.
1956: 26 Oct., 753
1957: 8 Mar., 423; 17 May, 964; 7 June, 1171; 13 Sept., 479

Biddle, James G., Co.
1957: 10 May, 947

Coleman Instruments, Inc.
1957: 15 Feb., 316; 24 May, 1055; 14 June, 1218; 13 Sept., 526; 11 Oct., 710

Perkin-Elmer Corp., Instrument Div.
1956: 16 Nov., 995; 7 Dec., 1179
1957: 1 Feb., 211; 8 Mar., 422; 31 May, 1066; 7 June, 1112; 2 Aug., 231

Standard Scientific Supply Corp.
1956: 30 Nov., 1054

Thomas, Arthur H., Co.
1957: 9 Aug., 280

Zeiss, Carl, Inc.
1957: 15 Feb., 265; 23 Aug., 334

STERILIZERS

Castle, Wilmot, Co.
1957: 15 Feb. 314; 26 Apr., 842; 21 June, 1258

Standard Scientific Supply Corp.
1956: 7 Dec., 1112

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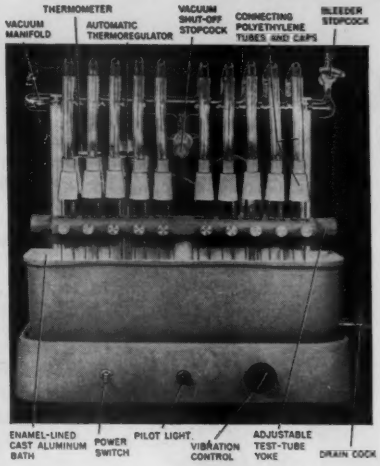

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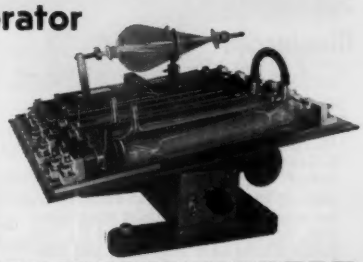

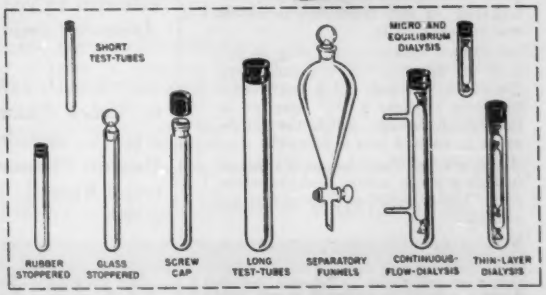

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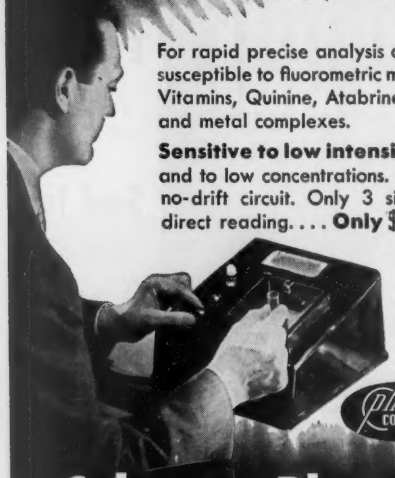

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STILLS

Smith, Arthur F., Co.
1957: 4 Oct., 664

STIMULATORS

American Electronic Laboratories, Inc.
1957: 4 Jan., 6; 18 Jan., 95; 6 Sept., 466

STIRRERS

Ace Glass, Inc.
1957: 10 May, 948
Central Scientific Co.
1956: 26 Oct., 742
Fisher Scientific Co.
1957: 19 July, 134

SYRINGE DRIVERS

Phipps & Bird, Inc.
1957: 21 June, 1255; 28 June, 1311; 27 Sept., 621; 18 Oct., 764

TELESCOPES

Edmund Scientific Corp.
1956: 26 Oct., 842; 23 Nov., 1046; 7 Dec., 1158
1957: 4 Jan., 32; 1 Feb., 204; 1 Mar., 412; 5 Apr., 660; 3 May, 896; 7 June, 1166; 12 July, 89; 2 Aug., 222; 6 Sept., 466; 4 Oct., 667
Fecker, J. W., Inc.
1957: 5 July, 40; 2 Aug., 224; 16 Aug., 322; 30 Aug., 414; 27 Sept., 622; 4 Oct., 662; 11 Oct., 714
United Scientific Co.
1956: 16 Nov., 994; 30 Nov., 1095; 7 Dec., 1172; 14 Dec., 1184
1957: 28 June, 1309

THERMOMETERS

Ace Glass, Inc.
1957: 12 Apr., 707
Sargent, E. H., & Co.
1957: 22 Feb., 372
Yellow Springs Instrument Co., Inc.
1956: 26 Oct., 840
1957: 15 Feb., 306

TIMERS

Standard Scientific Supply Corp.
1957: 21 June, 1256

TITRATION EQUIPMENT

Bach-Simpson, Ltd.
1956: 26 Oct., 752
Central Scientific Co.
1956: 26 Oct., 743
Linbro Chemical Co., Inc.
1956: 26 Oct., 766; 9 Nov., 912
1957: 11 Jan., 86; 15 Mar., 472; 24 May, 1018
Polarad Electronics Corp., Scientific Instruments Div.
1956: 26 Oct., 750; 16 Nov., 1003; 7 Dec., 1116
1957: 7 June, 1161; 4 Oct., 668
Sargent, E. H., & Co.
1957: 12 July, 53

TOOL KIT

Standard Scientific Supply Corp.
1956: 26 Oct., 761

TRANSPARENCIES

Polaroid Corp.
1957: 19 July, 98–99; 16 Aug., 282–283; 27 Sept., 589

TUBING, PLASTIC

U.S. Stoneware
1956: 26 Oct., 854; 16 Nov., 992; 14 Dec., 1221
Nalge Co., Inc.
1956: 16 Nov., 996
1957: 15 Mar., 514; 19 July, 136

VACUUM DRY BOX

Blickman, S., Inc.
1957: 15 Feb., 323; 23 Aug., 331

VACUUM GAUGE

National Research Corp., NRC Equipment Corp.
1956: 26 Oct., 832
1957: 15 Feb., 315; 6 Sept., 462
Smith, Arthur F., Co.
1957: 27 Sept., 593

VALVES

Phipps & Bird, Inc.
1957: 15 Feb., 262

VISCOMETERS

Fisher Scientific Co.
1956: 26 Oct., 835
Polarad Electronics Corp., Scientific Instruments Div.
1956: 26 Oct., 750; 16 Nov., 1003; 7 Dec., 1116
1957: 2 Aug., 225

WARBURG APPARATUS

Will Corp., Bronwill Scientific Div.
1957: 3 May, 899; 7 June, 1165; 6 Sept., 463

WARING BLENDOR

Waring Products Corp.
1957: 15 Mar., 515; 3 May, 866

WATER BATH

Sargent, E. H., & Co.
1957: 9 Aug., 234

WAXES

Biddle, James G., Co.
1956: 14 Dec., 1227
1957: 8 Mar., 461; 13 Sept., 524

WEIGHTS

Ainsworth, Wm., & Sons, Inc.
1956: 5 Apr., 659

X-RAY EQUIPMENT

Jarrell-Ash Co.
1956: 26 Oct., 764
Philips Electronics, Inc., Instruments Div.
1957: 6 Sept., 427; 20 Sept., 583; 11 Oct., 719

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Research Specialties Co.
1957: 27 Sept., 627

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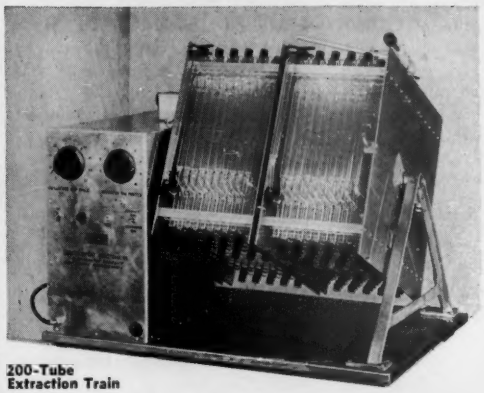

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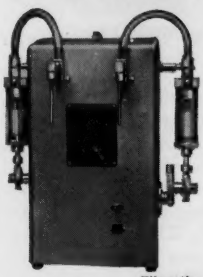

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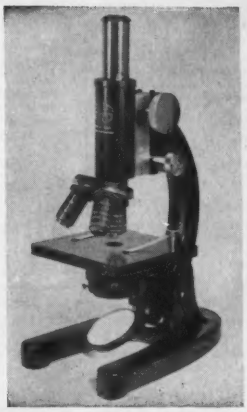

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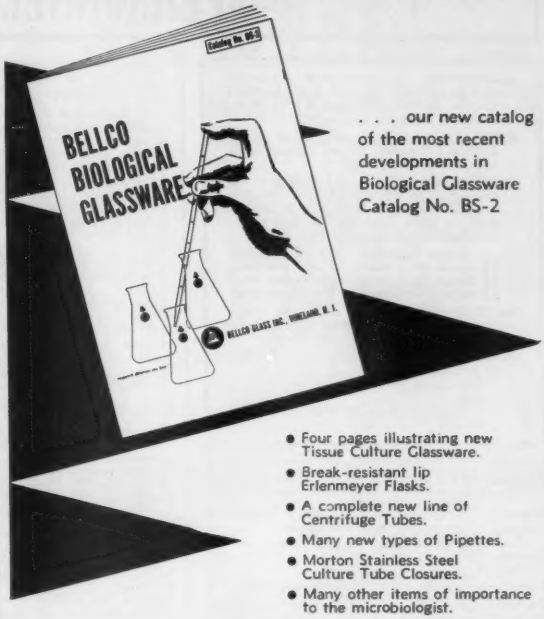

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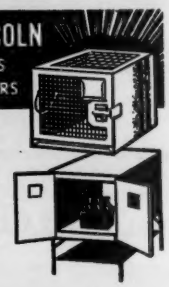

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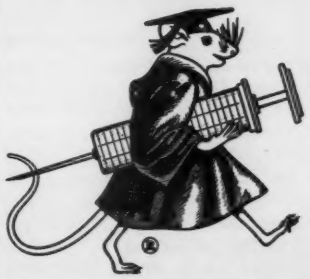

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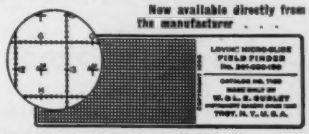

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4. Programs of the more than 60 participating societies.
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6. Details of the Murat Temple—center of the Meeting—and of the hotels and other session sites.
7. Titles of the latest foreign and domestic scientific films to be shown in the AAAS Science Theatre.
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Directory content

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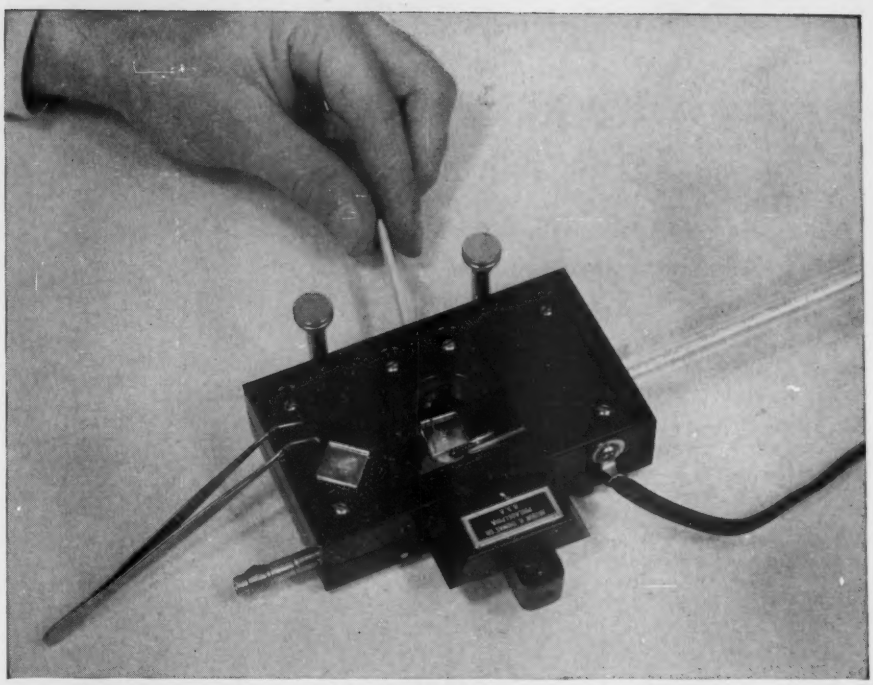

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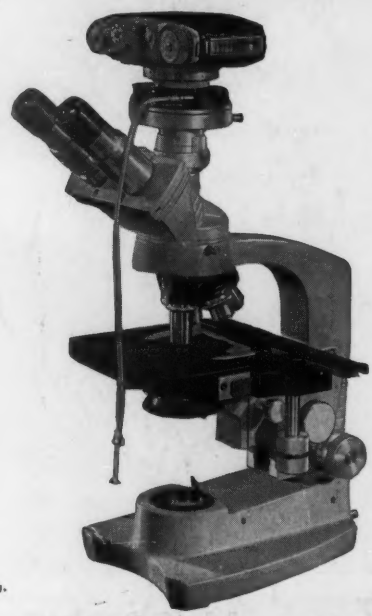

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